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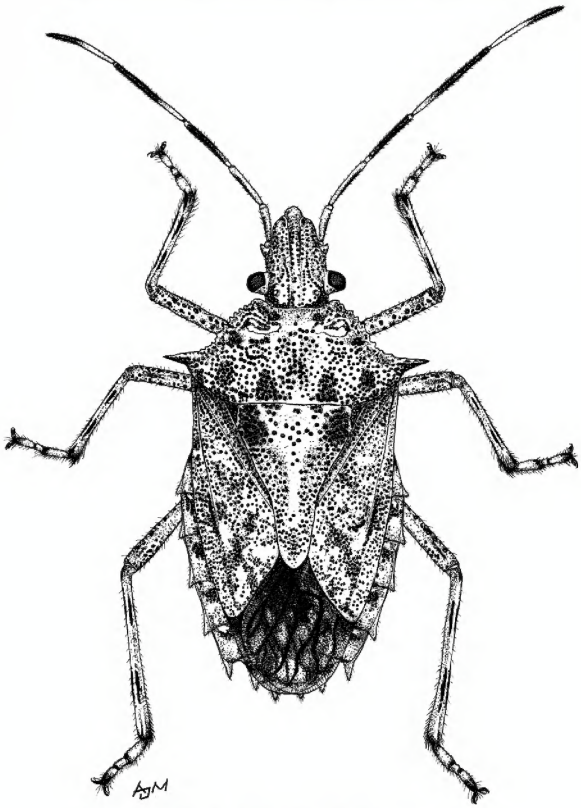

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COVER

Bromocoris souefi (Distant, 1910) (Hemiptera: Pentatomidae) was described by British hemipterist, W.L. Distant, from a specimen collected at Cooktown in 1896 by W.H.D. Le Souëf after whom it is named. He was son of the Director of the Melbourne Zoo and collected it on an expedition to collect tree kangaroos for the zoo. It occurs in Indonesia, New Guinea and northern Australia. Its range in Australia has recently expanded southerly and it has been common in Brisbane since 2006. Females brood and vigorously guard their eggs and first instars on the undersides of leaves of many tree species. The illustration is ink on paper by ESQ member Dr Andrew Maynard who received his UQ PhD in 2020 on the invasion history and evolution of *Aedes albopictus* and *Aedes aegypti* in the Indo-Pacific. He works in Brisbane at the Dept. of Agriculture, Water and the Environment as a biosecurity entomologist with special interest in Hemiptera. *Bromocoris souefi* is routinely intercepted.

AUSTRALIAN MEALYBUGS (HEMIPTERA: PSEUDOCOCCIDAE): RESURRECTION OF THE GENUS *AUSTRALIPUTO* WILLIAMS AND DESCRIPTION OF A NEW GENUS AND SPECIES ON *POMADERRIS* (RHAMNACEAE)

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Abstract

Taxonomic treatments for two genera of Australian native mealybugs (Hemiptera: Coccomorpha: Pseudococcidae) are presented. The genus *Australiputo* Williams, 1985 **stat. rev.** is resurrected from synonymy with *Ceroputo* Šulc, 1898, from which it is morphologically and biogeographically distinct. This action limits *Ceroputo* to the Holarctic. The two species of *Australiputo* revert to *Australiputo casuarinae* (Maskell, 1893) **stat. rev.** and *A. eucalypti* Williams, 1985 **stat. rev.** A new species in a new genus of mealybugs found on wild plants and horticultural plantings of several *Pomaderris* species (Rhamnaceae) from the Australian Capital Territory and New South Wales is described as *Glabracoccus pomaderris* **gen. n.** and **sp. n.** (subfamily Pseudococcinae). The adult female and first-instar nymph of *G. pomaderris* are illustrated and the possible relationships of *Glabracoccus* to other mealybug genera are discussed.

Key words: Pseudococcidae, mealybug, *Australiputo*, *Ceroputo*, *Pomaderris*

Introduction

Australia has a diverse fauna of mealybugs (Hemiptera: Coccomorpha: Pseudococccidae), comprising about 200 named species in at least 60 genera (García Morales *et al*. 2020). At least 80% of these species are native to Australia but most are poorly known and only a few are considered threatened (Moir 2020). The Australian mealybug fauna was documented comprehensively by Williams (1985) based almost entirely on museum collections and subsequent collecting has revealed many undescribed mealybug species on native Australian plants (Gullan *et al*. 2013; PJG, unpublished data). Opportunistic collections made in the Australian National Botanic Gardens (ANBG) in Canberra, Australian Capital Territory (ACT), during the early 1980s recorded 14 mealybug species belonging to eight genera (Gullan *et al*. 1987), including one new species of *Pseudococcus* Westwood, 1840 on *Xanthorrhoea* (Asphodelaceae) that was described formally by Qin and Gullan (1990). Another new species of *Pseudococcus* was described from an endangered *Banksia* species from Western Australia (Gullan *et al*. 2013), but now is considered to be extinct due to decimation of its host plant (Moir 2020). Also a new genus and new species, *Wapaococcus dougwilliamsi* Ben-Dov, 2007, was described from the roots of a grass in Western Australia.

This paper deals with two genera of endemic Australian mealybugs. One is resurrected from an unjustified synonymy and the other is newly described. In his taxonomic monograph on Australian mealybugs, Williams (1985) named the genus *Australiputo* for two distinctive species from southeast Australia. The taxonomy of this genus is re-visited in this paper because, without justification, Danzig and Gavrilov-Zimin (2014) synonymised *Australiputo* with the Holarctic

genus *Ceroputo* Šulc, 1898, which they incorrectly consider to be a subgenus of *Puto* Signoret, 1876. Here the morphology of *Australiputo* is re-assessed and compared with that of the type species of *Ceroputo*.

A morphologically distinctive pseudococcid taxon was discovered when the author was asked to identify mealybugs that were infesting nursery plants of rare and threatened species of *Pomaderris* (Rhamnaceae) at the ANBG. Subsequently, the same mealybug species was collected on *Pomaderris eriocephala* N.A. Wakef. at the author's property at Oallen in New South Wales (NSW), about 100 km NE of Canberra. At about the same time in 2018, photographs of this distinctive mealybug from another *Pomaderris* species at Bywong, NSW, were sent to the author for identification. This mealybug species does not appear to be represented in any museum collections and has never been seen previously by the author. It could not be placed in any described pseudococcid genus. Here the species is described as new to science and a new genus is erected for it.

Materials and methods

Adult females of *Australiputo* and *Ceroputo* were available on microscope slides held in the Australian National Insect Collection (ANIC) CSIRO, Canberra, or will be deposited in the ANIC by the present author. Live specimens of the mealybugs collected on *Pomaderris* species were preserved in 75% and 100% ethanol. For microscope examination, these specimens were slide-mounted in Canada balsam using the method described in Gullan (1984), which is similar to the method of Williams and Granara de Willink (1992) except that xylene washes were used instead of clove oil prior to mounting in Canada balsam. The mealybugs from *Pomaderris* were mounted one adult female per slide and nymphs 3–14 per slide. Most of these microscope slides have been deposited in ANIC, but two adult female paratypes will be deposited in the Department of Primary Industries Insect Collection, Brisbane, Queensland (QDPC). Host plants, except those at the ANBG, were identified by J. Walker (see Acknowledgements).

Most morphological terms used in the descriptions are explained by Williams (1985). Information on antennal sensilla comes from Koteja (1980), Ahmad *et al.* (2013) and Wang *et al.* (2018), although Ahmad *et al.* (2013) used a very broad definition of basiconic sensilla that appears to be incorrect. A slightly simplified naming scheme for antennal sensilla is adopted here as the different types can be difficult to distinguish and require detailed study, and are not important for identification of closely related taxa. Trichoid sensilla are hair-like or flagellate but of varying thickness and length, each with a well-defined socket; fleshy setae (including multiporous pegs and sensilla chaetica) are thick and curved, each with a rounded apex and a less obvious socket; basiconic sensilla are stout and conical, each with a pointed apex and rarely reach 11 µm long; coeloconic sensilla are only a few µm long, each situated at the base of an invagination; and campaniform sensilla are pore-like structures on the pedicel or the legs that function as proprioceptors. The outer part of the anal ring of the adult females has a row of sensillum-like structures that were illustrated but not described by Ferris

(1950, figure 3) and also by Danzig & Gavrilov-Zimin (2014, figures 1.1–2 and 1.1–3) who referred to them as spinulae. Under oil using the 100x objective, each structure has a globular base and bears a thick seta-like projection with a rounded apex, suggesting a mechanoreceptive function, although a secretory function might be possible. Each of these structures resembles a rimmed circle at lower magnification and, if mentioned in descriptions, usually they are referred to as cells. All measurements of morphological structures are maximum dimensions (e.g. body width and femur width were recorded at the widest points) and are expressed as the range. Lengths of leg segments were measured medially. Tarsal length excludes the claw. Spiracle length includes the muscle plate (apodeme). Setal length includes the setal base. The illustrations of the adult female and the first-instar nymph of the new species each represent a generalised individual, based on several of the specimens used for the description. The central drawing shows the venter on the right and the dorsum on the left. Enlargements around the central drawing are not drawn to the same scale.

Systematics

Australiputo Williams stat. rev.

zoobank.org:act:88B9A499-46E1-475B-A80A-437EF5F178E6

Australiputo Williams, 1985: 60. Type species: *Pseudococcus casuarinae* Maskell, 1893, by original designation.

Ceroputo Šulc, 1898: 1. Incorrect synonymy by Danzig and Gavrilov-Zimin 2014: 169.

Williams (1985) erected the mealybug genus *Australiputo* to include two Australian species, *A. casuarinae* (Maskell, 1893) and *A. eucalypti* Williams, 1985, and noted that both had about 25 pairs of cerarii and completely lacked any dorsal cerarii, ventral multilocular disc pores or quinquelocular pores. He suggested an affinity of *Australiputo* with *Puto* Signoret, but it is clear now that *Puto* is not a genus of Pseudococcidae but belongs to its own family, Putoidae (Hodgson and Foldi 2006; Gullan and Cook 2007; Williams *et al.* 2011). Williams *et al.* (2011) reviewed the taxonomic history and characteristics of *Puto* and concluded that a few species of the mealybug genus *Ceroputo* had been placed into *Puto* incorrectly. These misplaced species included *C. pilosellae* Šulc, 1898, the type species of *Ceroputo*. In addition to differences in chromosome systems and nucleotide sequence data, species of Putoidae are distinct from those of Pseudococcidae in the morphology of adult females, adult males and first-instar nymphs, as discussed by Williams *et al.* (2011). In contrast to the previous studies, Gavrilov-Zimin and Danzig (2012) argued that *Puto* should be part of the Pseudococcidae and that it should include two subgenera *Puto* and *Ceroputo*. Such a classification is inconsistent with detailed evidence based on morphology, chromosome systems and DNA data (Hardy *et al.* 2008; Williams *et al.* 2011; Kaydan *et al.* 2015).

More recently, Danzig and Gavrilov-Zimin (2014) considered *Australiputo* to be a subjective synonym of their subgenus *Ceroputo*, although they did not examine specimens of *Australiputo*. My detailed comparison of the adult females of the two named species of *Australiputo* showed that they differ from the female of the type species of *Ceroputo* as follows (features of *C. pilosellae* in parentheses): body margin with 25 pairs of distinct cerarii, each on a sclerotised area, plus several smaller clusters of setae and trilocular pores (18 pairs and no smaller clusters); cerarian setae conical (lanceolate to conical with flagellate apex); multilocular and quinquelocular disc pores absent (both present); body large, 5.0–8.5 mm long, shape broadly oval (up to 3.5 mm long, oval); antennal segments II–V each long relative to width, with L:W ratio of each of these segments 4.0–6.5 (ratios of 2.1–3.1); and labium with acute apex and about 1/6 size of clypeolabral shield (apex rounded, only slightly smaller than clypeolabral shield). For mealybug taxonomy, the above differences are highly significant. The adult female of *C. pilosellae* is a typical phenacoccine mealybug (Kaydan *et al.* 2015), whereas the adult females of the two species of *Australiputo* look unusual. Although *Australiputo* currently is placed in the Phenacoccinae (Hardy *et al.* 2008), the morphology of the adult females only partly fits this subfamily. The *Australiputo* species are known only from endemic Australian plant species. The type specimens of *A. casuarinae* were collected on an unidentified species of "*Casuarina*" (Casuarinaceae) [this might be *Allocasuarina* rather than *Casuarina*], whereas *A. eucalypti* has been collected a number of times from under the bark of *Eucalyptus* species (Myrtaceae). It is concluded here that any resemblance of *Australiputo* to *Ceroputo* is due to convergence. Thus *Australiputo* is resurrected from synonymy with *Ceroputo*, and *A. casuarinae* **stat. rev.** and *A. eucalypti* **stat. rev.** revert to *Australiputo*.

Following removal of *Australiputo* species from *Ceroputo*, the latter genus now contains seven species, with five from the Palaearctic and two from the Nearctic (the latter both from California) (García Morales *et al.* 2020). Further study of *Ceroputo* is warranted because it is not clear from morphology that the Californian species are congeneric with the Palaearctic species.

Specimens and literature examined: *Australiputo casuarinae* (Maskell): 2 adult females, mounted from Maskell's type collection ex New Zealand Arthropod Collection, Landcare Research, Auckland, by H.M. Brookes, Specimen Index No. 55/65 (ANIC). *Australiputo eucalypti* Williams: holotype adult female from Tintinara, South Australia (ANIC), plus 9 other adult females from 8 localities in South Australia, Victoria, New South Wales and the Australian Capital Territory (all in ANIC); plus illustrations and descriptions in Williams (1985).

Ceroputo pilosellae Šulc: 3 adult females, ex *Hieracium* sp. (Asteraceae), Poland, Opaleniska, 50°08'49" N, 22°24'48" E, 15 Aug. 2001, B. Łagowska (PJG collection to be deposited in ANIC); plus illustrations and descriptions in Danzig (1980), Kosztarab & Kozár (1988), Marotta & Tranfaglia (1993) and Danzig & Gavrilov-Zimin (2014).

Figs 1, 2. Live mealybugs of *Glabracoccus pomaderris* **sp. n.**: (1) leaves of *Pomaderris eriocephala* with adult and nymphal females and some black sooty mould on stem and foliage, Oallen, NSW; (2) underside of a leaf of *P. brunnea* with 5 adult females and numerous nymphs, Australian National Botanic Gardens, Canberra, ACT. Photos: P.J. Gullan.

Glabracoccus gen. n.

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Type species. Glabracoccus pomaderris **sp. n.**, by monotypy.

Description. Adult female in life mostly devoid of wax except for glassy filaments, each produced from a conical spine-like seta. On microscope slides, body of adult female ovoid and derm membranous except for light sclerotisation on anal lobes and around bases of a few large dorsal setae. Eyespots prominent. Antennae each with 7 segments. Labium elongate conical, 3 segmented, with length up to 2.7 times basal width. Spiracles typical for mealybugs. Legs well developed, with some translucent pores at least on dorsal surface of coxa and in a cluster on dorsal surface of trochanter. Circulus absent. Anterior and posterior ostioles well developed, each with setae and trilocular pores on anterior and posterior lip. Anal ring with 6 setae. Body setae of 2 types: (1) conical spine-like, of varying sizes up to 60 µm long on dorsum and extending to ventral submargins, each larger dorsal seta usually associated with a few trilocular pores around its base, with spine-like setae most abundant on dorsum where they form sparse transverse rows or bands on most segments; and (2) flagellate setae, of varying sizes, up to 100 µm long, longest on ventral abdomen and head, with short setae up to 15 µm long scattered on venter and dorsum. Cerarii well developed only on posterior abdominal segments, with loose clusters of conical spine-like setae and trilocular pores present more anteriorly on body margin of abdomen; at least each anal lobe cerarius situated on a sclerotised area and with more than 2 conical spine-like setae, 1 very short thin seta and a number of associated trilocular pores. Trilocular pores each almost circular in outline, with 3 loculi not swirled as obviously as in most other mealybug taxa. Discoidal pores sparsely scattered on dorsum and venter. Oral collar tubular ducts present only on venter of abdomen. Oral rim tubular ducts and multilocular pores absent.

Morphological features considered to be diagnostic of this new monotypic genus are listed above; however, features of generic importance might need to be re-assessed if additional species are discovered. Diagnostic comments on this new Australian mealybug taxon are provided after the species description of the adult female.

Etymology. The genus name is formed from the Latin word "glaber" meaning naked, combined with the name *Coccus* that was the first genus name used for scale insects. The name refers to the lack of powdery wax on adult females and nymphs and is of masculine gender.

Glabracoccus pomaderris sp. n.

(Figs 1–4)

zoobank.org:act:2F910094-5BDB-46DE-BE21-C1B03C7F1A4D

Type material. Holotype, adult female, ex underside of leaf of *Pomaderris eriocephala,* AUSTRALIA, New South Wales, Oallen, 1760 Oallen Ford Road, 'NeverDie', -35.129104, 150.013517, 31 Jan. 2018, P.J. Gullan, ANIC registration no. 20-011153 (ANIC).

Paratypes: 11 adult females, same data as holotype, except collected 28 Mar. 2018 (9 in ANIC including voucher LGC04087, 2 in QDPC); 11 adult females (including voucher LGC04027) and 15 slides with 21 third-instar females (including 3 each containing a pharate adult), 23 second-instar nymphs (including 2 each containing a pharate third-instar female) and 63 first-instar nymphs (including 3 each containing a pharate second-instar nymph), ex underside of leaves of *Pomaderris brunnea* N.A. Wakef., Australian Capital Territory, Canberra, Australian National Botanic Gardens, nursery, under shade cloth, -35.271115, 149.109646, 20 Feb. 2017, B. Clarke & P.J. Gullan (ANIC).

Description of adult female (measurements based on 16 slide-mounted specimens). In life (Figs 1, 2): body pale cream, almost devoid of powdery white wax but with glassy filaments (each 0.1–0.6 mm long) around body margins and submargins and a few usually shorter filaments (<0.2 mm) more medially on dorsum. On microscope slides (Fig. 3): body ovoid, length 1.4–2.2 mm, width 0.8–1.6 mm; segmentation distinct; derm membranous except for light sclerotisation on anal lobes and around bases of larger conical spine-like setae on abdomen. Eyespots each 45–60 µm wide. Antennae each 310–410 µm long, with 7 segments; apical segment 70–100 µm long, 20–27 µm wide; trichoid sensilla on every antennal segment, each seta 20–32 µm long, curved, except apical seta straight, 27–30 µm long; fleshy setae each 20–28 µm long, numbering 1 on segment VI, 4 on VII; basiconic sensilla not observed; 2 coeloconic sensilla present near apex of VII; a single campaniform sensillum on dorsal apical part of II. Labium elongate conical, 3 segmented, 220–280 µm long, 85–100 µm wide across base, with 9 pairs of flagellate setae (3 pairs on basal segment, 1 pair on medial and 5 pairs on apical segment), 3 pairs of apical bristles and 1 pair of short apical bristles. Clypeolabral shield (tentorium) 140–160 µm long. Mesothoracic spiracles each 50–65 µm long including apodeme, 25–30 µm wide across peritreme; metathoracic spiracles each 55–70 mm long including apodeme, 30–37 µm wide across peritreme. Legs well developed; hind legs each with some translucent pores dorsally: scattered on coxa (mostly 20–50, but sometimes not visible), 5–16 in a cluster on trochanter, and either absent from or present on proximal half of femur (4–14), absent from other segments; hind coxa 160–200 µm long, hind trochanter + femur 280–310 µm long, hind tibia + tarsus 295–350 µm long, claw curved, 35–42 µm long; hind femur 70–95 µm wide; hind trochanter with longest seta 100–130 µm long; each pair of legs with tarsal digitules capitate, subequal on mid and hind legs, 50–62 µm long, but on fore legs one thinner and shorter (38–45 µm long) than other (50–55 µm); claw digitules capitate, each 30–40 µm long; claw denticle not discernible. Ratio of lengths of hind tibia + tarsus to trochanter + femur 1.0–1.2; ratio of lengths of hind tibia to tarsus 2.1–3.1. Circulus absent. Both pairs of ostioles well developed; anterior ostioles each 90–125 µm wide, each lip with 8–14 trilocular pores and 2–5 small setae, anterior lip also with 1 conical spine-like seta; posterior ostioles each 85–120 µm wide, each lip with 9–17 trilocular pores and 3–5 small setae, anterior lip also with 1 slightly larger seta. Anal ring 70–90 µm in outside width, with opening 40–60 µm wide, ring bearing 6 anal ring setae, each 140–190 µm long, and an inner row of up to 35 irregularly-shaped elongate cells and an outer irregular row of up to 30 sensillum-like structures each

5–8 µm high with a globular base 2–4 µm across and a seta-like projection 4.0–5.5 µm long with a rounded apex. Anal lobes moderately developed, each with an elongate sclerotised area ventrally and an apical seta 120–150 µm long, but no anal lobe bar. Cerarii fully developed and situated on a sclerotised area only on anal lobe and penultimate abdominal segments; however, diffuse marginal clusters of conical spine-like setae and associated trilocular pores usually present on a few preceding abdominal segments, especially segments V and VI that often each have a cerarius with 2 larger conical spine-like setae, each with sclerotisation around the base and a small cluster of trilocular pores; each anal lobe cerarius with 3–8 conical spine-like setae, longest 50–60 µm long, with 2 or 3 sometimes smaller than other setae, plus 1 shorter thin seta 10–17 µm long, and 7–14 associated trilocular pores; each penultimate cerarius with 4–8 conical spine-like setae, plus 1–3 shorter thin setae each 10–18 µm long, and 4–9 associated trilocular pores.

Dorsum with minute microtrichia medially to submedially on derm of posterior abdomen. Setae of 2 types: (1) conical spine-like setae each 13–60 µm long, the larger ones each with 1–5 trilocular pores and a ring of sclerotisation around setal base, the latter more obvious in mature females, all sizes of setae distributed in segmental rows on posterior abdominal segments and in broad, scattered bands on all other segments, and marginally forming either diffuse clusters or part of cerarii on posterior abdomen; and (2) short robust, flagellate setae, each 7–12 µm long, sparsely scattered. Trilocular pores each 4–5 µm in diameter, scattered sparsely across all segments and concentrated around bases of larger setae (see above). Discoidal pores, mostly each 2.5–3.0 (rarely 3.5) µm in diameter, very sparsely scattered. Multilocular pores absent. Oral collar and oral rim tubular ducts absent.

Venter with minute microtrichia medially to submedially on derm of abdomen and medially on at least thoracic segment III. Setae of 2 types: (1) conical spine-like setae from margin to submargin, each 10–50 µm long, same type as on dorsum; and (2) flagellate setae, each mostly 10–80 µm long, longer on head (up to 100 µm) and posterior abdomen (up to 110 µm), sparsely distributed across each abdominal segment, with medial to submedial setae longest, and marginal to submarginal setae all very short (each 6–15 µm) and quite robust, same type as on dorsum. Trilocular pores mostly each about 4 µm in diameter, scattered submedially to marginally on all segments, almost absent medially on anterior abdomen. Discoidal pores same size as on dorsum, very sparsely scattered. Multilocular pores absent. Oral collar tubular ducts, each 6–8 µm long and 2.5–3.0 µm in diameter, with rounded inner end and no inner filament, only 1–4 ducts on each of abdominal segments VI and VII. Oral rim tubular ducts absent.

Comments. Adult females from the two populations sampled were very similar in morphology, with only one leg character varying between the two localities. Most adult females from the collections at NeverDie had a shorter tibia than the females from the ANBG, resulting in a smaller ratio of lengths of hind tibia to hind tarsus (2.1–2.5) compared with the ANBG females (2.4–3.1).

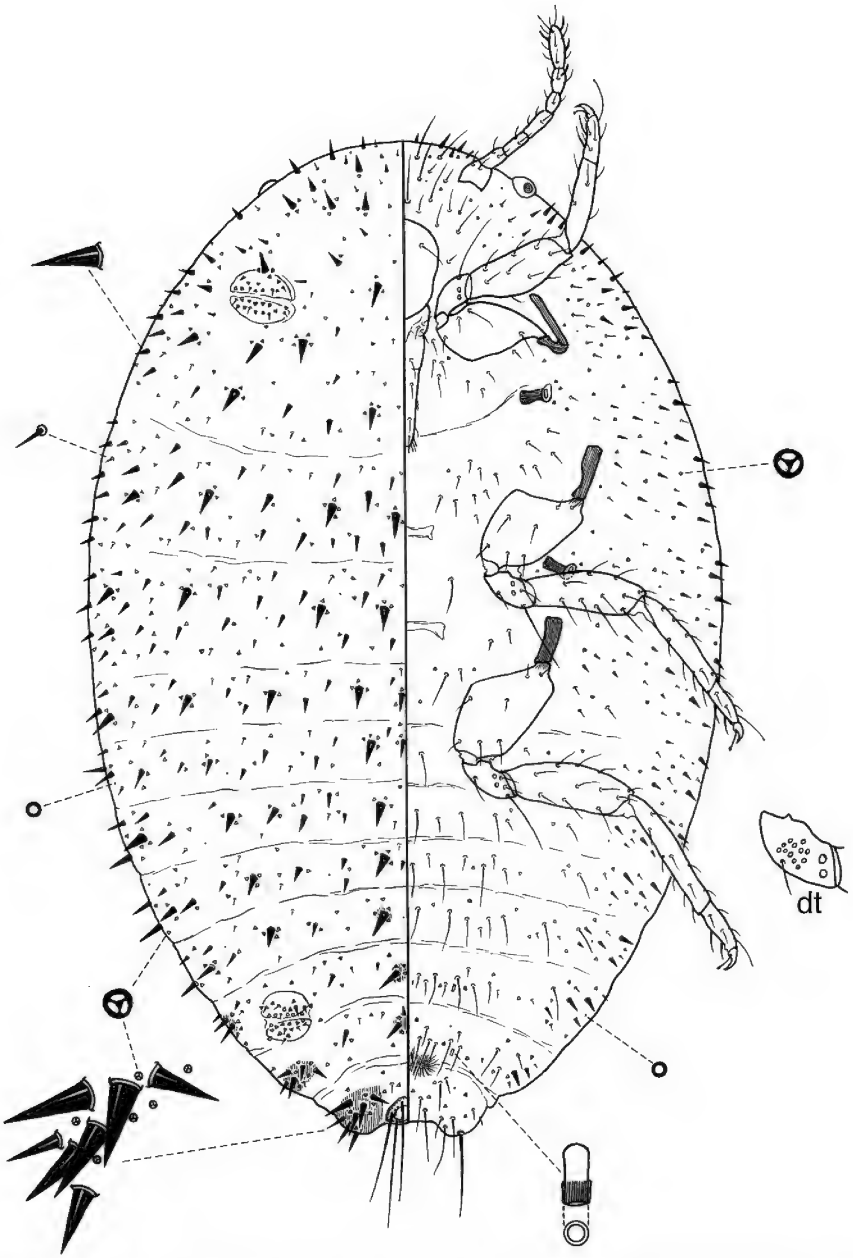

Fig. 3. Taxonomic illustration of the adult female of *Glabracoccus pomaderris* **sp. n.** with dorsum on left and venter on right. dt = dorsum of trochanter.

Description of first-instar nymph (measurements based on 8 slide-mounted specimens) (Fig. 4).

In life: body pale cream to white with short glassy filaments around margins and on dorsum, longest on posterior abdomen; eyespots black. On microscope slides: derm membranous except for small area around setae at apex of each anal lobe and around base of pair of medial dorsal setae on abdominal segment VII. Body 370–460 µm long, 180–235 µm wide; segmentation distinct, especially on abdomen. Eyespots each 15–20 µm wide, situated on body margin. Antennae each 160–175 µm long, with 6 segments; segment VI longest, 60–65 µm long, 20–23 µm wide; trichoid sensilla, each 12–25 µm long, distributed as follows: 3 on segment I, 3 on II, 3 on III, 5 on IV, 5 on V, up to 16 on VI including apical seta; fleshy setae each 18–23 µm long, distributed as follows: 1 on V, 4 on VI; basiconic sensilla not observed; 2 coeloconic sensilla present near apex of VI; a single campaniform sensillum on dorsal apical part of segment II. Labium conical, 3 segmented, 85–90 µm long, 43–50 µm wide across base, with 7 pairs of flagellate setae (3 pairs on basal segment, 1 pair on medial and 3 pairs on apical segment), 3 pairs of apical bristles and 1 pair of short apical bristles. Clypeolabral shield 75–80 µm long, 60–70 µm wide. Spiracles including peritreme each 23–30 µm long and 7.5–9.0 µm wide across atrium, with 1 trilocular pore anterolateral and 1 posterior to atrial opening. Legs well developed, subequal in size; hind trochanter + femur 80–90 µm long, hind tibia + tarsus 120–130 µm long, claw curved, 18–21 µm long; hind femur 30–35 µm wide; trochanter of each leg with 1 very long distal seta, 35–45 µm long; tarsal digitules minutely capitate, 1 slightly thinner than the other, each pair subequal in length on all legs, 27–35 µm long on fore legs, 25–33 µm long on mid and hind legs; claw digitules capitate, all about 15 µm long; claw denticle barely discernible. Ratio of lengths of hind tibia + tarsus to trochanter + femur 1.44–1.59; ratio of lengths of hind tibia to tarsus 0.78–0.86. Circulus absent. Both pairs of ostioles well developed; anterior ostioles each 25–30 µm wide, each lip with 1 trilocular pore and anterior lip also with 1 robust conical seta 10–12 µm long on outer edge; posterior ostioles each 25–35 µm wide, each lip with 1 trilocular pore and anterior lip also with 1 small seta about 6 µm long. Anal ring 28–30 µm wide, with 6 anal ring setae, each 42–50 µm long, and an inner and outer row each of 7–9 cells or cell-like structures, usually obscured due to orientation of anal ring. Anal lobes moderately developed, each lobe with a small sclerotised area dorsally bearing 2 spine-like cerarian setae, each 15–20 µm long, and 2 trilocular pores, and ventrally with 1 flagellate seta up to 26 µm long and an apical seta 45–55 µm long. Cerarii present marginally on each abdominal and thoracic segment; each cerarius composed of 1 trilocular pore and a pair of separated setae, with the more ventral seta of each pair smaller (5–10 µm long) than the more dorsal seta (8–15 µm long); cerarian setae of anal lobe described above.

Dorsum with faint mediolongitudinal band of sparse microtrichia on abdomen. Setae conical, spine-like, each 6–18 µm long, distributed in a transverse row of 8 setae per segment including 2 cerarian setae on each side of body (except segment

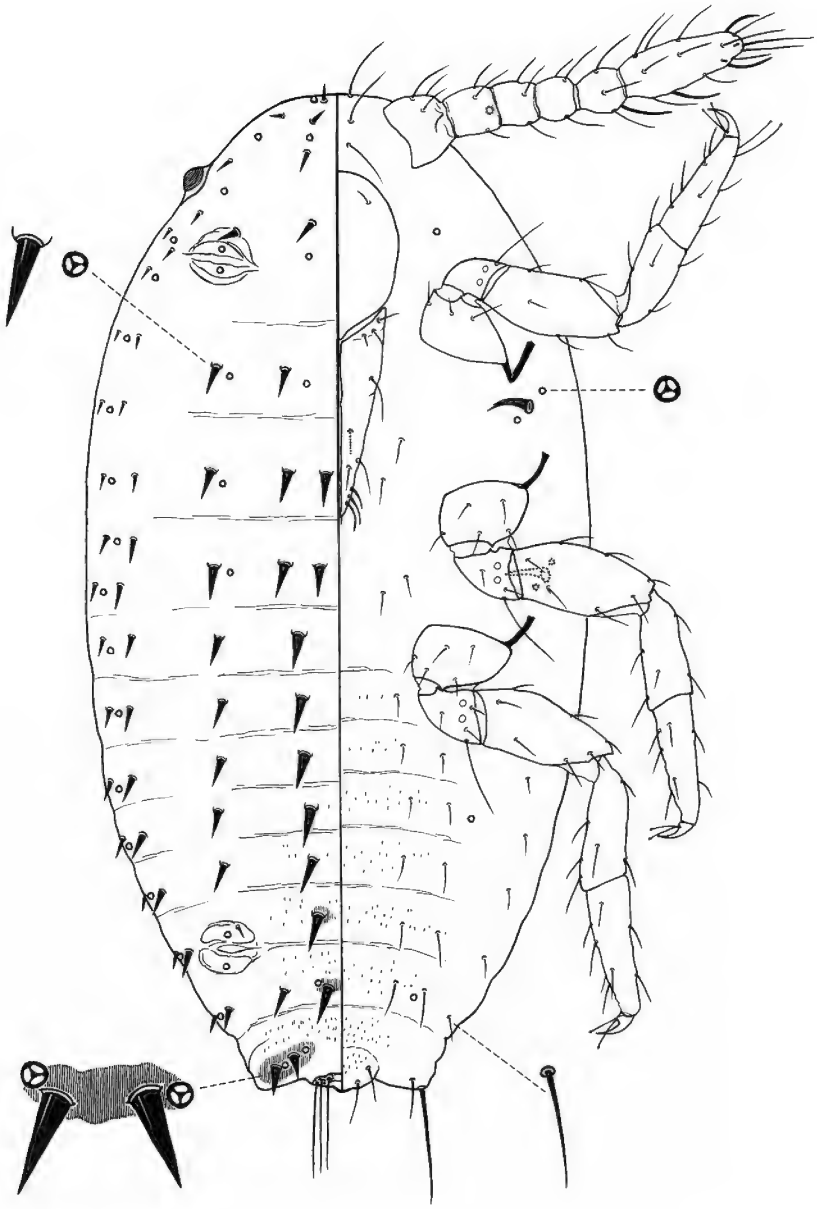

Fig. 4. Taxonomic illustration of the first-instar nymph of *Glabracoccus pomaderris* **sp. n.** with dorsum on left and venter on right.

VIII with anal lobe setae only), segmentally arranged but lines often more difficult to discern on thorax and head; setae of adjacent body segments lining up to form 4 pairs of longitudinal rows: 1 medial, 1 submedial, 1 submarginal and 1 marginal, with setae of the latter 2 lines forming cerarii (more ventral seta of each cerarius smaller, see above). Trilocular pores each 3.0–3.5 μm in diameter, their distribution rather variable, with 1 pore next to several medial, submedial and/or submarginal dorsal setae on head, thorax and abdomen (usually 14–20 pores in total, excluding those on ostioles and anal lobes and in cerarii on body margins), but almost always with each seta of medial dorsal pair on abdominal segment VII associated with 1 pore lateral to setal base. Multilocular pores and tubular ducts absent.

Venter with mediolongitudinal band of sparse microtrichia on abdomen. Flagellate setae mostly each 10–25 μm long, but 3 pairs of setae medially on head, each 25–40 μm long; other setae distributed as follows: 2 pairs medially to submedially on each of mesothorax and metathorax, and 6 setae in a transverse row across each abdominal segment (except on posterior abdomen where only 2 pairs submedially near anal ring); with setae of adjacent segments lining up to form 3 pairs of longitudinal rows: 2 submedial and 1 submarginal. Trilocular pores each 3.0–3.5 μm in diameter, with 2 adjacent to each spiracle (see above), 1 pore between eyes and clypeolabral shield on each side of head and 1 pore submedially on each side of abdominal segments III and VII. Multilocular pores and tubular ducts absent.

Comments. More than 30 first-instar nymphs were examined, although measurements and counts were taken only from eight nymphs that were well cleared and well displayed. All nymphs were extremely similar in morphology except for some variation in the number and position of trilocular pores adjacent to the conical spine-like setae on the dorsum.

Etymology. The species name refers to the host-plant genus and is a noun in apposition.

Discussion

Taxonomic affinities. Features of the adult females of *Glabracoccus* considered to be of taxonomic significance are: (1) the conical spine-like setae, especially the larger dorsal and marginal ones, each of which produces a long filament of glassy wax; these filaments resemble the hairs on the underside of the leaves of the host plants; some eriococcids produce similar filaments from enlarged dorsal setae but in the latter taxa there are microducts at the base of each secretory seta; (2) the absence of multilocular pores, particularly in combination with extremely few tubular ducts, both of which produce secretions that typically coat the body and eggs in wax; (3) the almost circular shape of the rim of each trilocular pore and the less-swirled appearance of the three loculi compared with typical mealybugs; (4) the unusually elongate labium; (5) possession of two pairs of prominent ostioles; and (6) 7-segmented antennae. The adult female of *G. pomaderris* shares a few features with the adult females of the Australian genus *Ventrispina* Williams,

1985, which are known only from surface litter and soil on Mt Kosciuszko in NSW. The adult females of *Ventrispina* resemble the female of *G. pomaderris* in having enlarged (spine-like) dorsal setae similar in shape to cerarian setae and with trilocular pores concentrated near the base of some setae, and two of the species have prominent ostioles. However, *Ventrispina* is part of the blue-black group of mealybugs that have coloured body pigments (Williams 1985), whereas *G. pomaderris* does not possess such pigments. *Ventrispina* species also have much smaller dorsal setae that are lanceolate, in contrast to the conical setae of *Glabracoccus*, and all three species of *Ventrispina* have trilocular pores and a labium of typical mealybug shape, as well as 6-segmented antennae; in addition, two of the species have multilocular pores that are lacking in *G. pomaderris*. *Ventrispina* belongs to the pseudococcid subfamily Pseudococcinae, in which the adult females typically have capitate tarsal digitules, no claw denticle, no quinquelocular pores and antennae with fewer than nine segments (Hardy *et al.* 2008). *Glabracoccus* also fits well into this subfamily.

In having prominent dorsal setae, *Glabracoccus* shows some resemblance to *Neoclavicoccus* Cohic, 1959 from New Caledonia, *Pedrococcus* Mamet, 1942a from Indonesia (Bali), Malaysia (Sabah), Madagascar, Mauritius and the Solomon Islands, and *Pedronia* Green, 1922 from Sri Lanka (see Williams (2004) for excluded species), although the adult females of the latter three genera all have many clusters of spine-like setae on sclerotised bases or prominences on the dorsum as well as forming marginal cerarii (Mamet 1942a,b; Williams & Watson 1988; Williams 2004). Furthermore, the species of *Neoclavicoccus*, *Pedrococcus* and *Pedronia* that are illustrated adequately in the literature each have a labium of typical mealybug shape and the trilocular pores appear triangular with typically swirled loculi. The adult female of *Glabracoccus* differs from the females of *Neoclavicoccus* species (features of latter in parentheses) in having cerarii each on a flat sclerotised area and restricted to the posterior abdomen (17 pairs of cerarii, each on a sclerotised hemispherical prominence), antennae each with 7 segments (8 segments), multilocular pores absent (present on ventral abdomen), and tubular ducts only on posterior ventral abdomen (absent). It differs from *Pedrococcus* (features in parentheses) in having cerarii on sclerotised areas restricted to margins and dorsal midline of posterior abdomen (cerarii usually numbering 16 or 17 marginal pairs plus additional cerarii over dorsum, each on a sclerotised and sometimes elevated area), trilocular pores of one size (trilocular pores of two sizes in most species, including minute pores surrounding the base of each conical seta), multilocular pores absent (present on ventral abdomen), and tubular ducts only on posterior ventral abdomen (present or absent). It differs from *Pedronia* (features in parentheses) in having cerarii on sclerotised areas restricted to margins and dorsal midline of posterior abdomen (cerarii numbering 16 marginal pairs plus additional cerarii over dorsum, each on a sclerotised area), translucent pores in a cluster on each hind trochanter (absent from trochanter), multilocular pores absent (present on ventral abdomen), and tubular ducts only on posterior ventral abdomen (absent). It is most likely that any similarity of

Glabracoccus to the three non-Australian genera discussed above is due to convergence. Although DNA was extracted and stored from two adult females of *G. pomaderris* by L.G. Cook (University of Queensland), no molecular data or appropriately preserved specimens are available for any species of *Ventrispina* or the non-Australian genera discussed above.

Distribution and biology. *Glabracoccus pomaderris* has been recorded only from the ACT and nearby areas of the Southern Tablelands in NSW. However, the potted *Pomaderris* plants grown in the nursery at the ANBG had been sourced from Capertee Valley at ca. 750 m elevation on the west bank of the Capertee River in NSW; thus it is possible that the mealybugs were introduced to the ANBG from that location. In addition to the collections from Oallen, this mealybug occurs in Bywong, to the northeast of the ACT, as evidenced by a photograph of a live mealybug sent to the author for identification. At Bywong, the mealybugs infested garden plants of *Pomaderris pauciflora* N.A. Wakef., which subsequently died despite being watered in the drought. At Oallen, infested plants of *P. eriocephala* were water-stressed due to drought and the smallest plants (each about 0.5 m high) had died by early 2019. The plant deaths might have been caused by drought, since nearby larger plants infested by mealybugs were healthy. At the nursery in the ANBG, infested plants of *P. brunnea* N.A. Wakef. were well watered and healthy and the mealybugs were not causing any noticeable damage. At the times of field collection of this mealybug from late summer through early autumn of 2017 and 2018, the region was in drought and it is possible that host-plant water stress was favourable to mealybug growth and survival. Heavily infested plants had blackened stems and leaves (Fig. 1) from sooty mould growing on honeydew deposited by the mealybugs. It is not known whether this species reproduces sexually or by parthenogenesis. Male nymphs and adults were not seen.

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References

AHMAD, A., SHARMA, K.K. and RAMAMURTHY, V.V. 2013. First-instar nymphal morphology and antennal sensilla in *Kerria lacca* (Kerr, 1782) and *Paratachardina mahdihassani* (Kondo and Gullan, 2007) [parentheses used in error] (Hemiptera: Tachardiidae). *Zoologischer Anzeiger* **253:** 11–20.

BEN-DOV, Y. 2007. *Wapoacoccus dougwilliamsi* n. gen., n. sp. of leg-less mealybug from Australia (Hemiptera. Coccoidea, Pseudococcidae). *Bulletin de la Société Entomologique de France* **112:** 477–480.

COHIC, F. 1959. Contribution à l'étude des cochenilles de Nouvelle-Calédonie (Hom.) *Neoclavicoccus ferrisi* n. g., n. sp. et *Neoclavicoccus bugnicourti* n. sp. *Bulletin de la Société Entomologique de France* **64:** 88–91.

DANZIG, E.M. 1980. *Coccoids of the Far East of the USSR (Homoptera, Coccinea) with phylogenetic analysis of scale insect fauna of the world.* Nauka, Leningrad; 367 pp. [Also as a 1986 English translation: Oxonian Press Pvt. Ltd, New Delhi; 450 pp.]

DANZIG, E.M. and GAVRILOV-ZIMIN, I.A. 2014. *Palaearctic mealybugs (Homoptera: Coccinea: Pseudococcidae), Part 1: Subfamily Phenacoccinae.* Russian Academy of Sciences, Zoological Institute St. Petersburg; 678 pp.

FERRIS, G.F. 1950. *Atlas of the Scale Insects of North America. (ser. 5) [v. 5]. The Pseudococcidae (Part I).* Stanford University Press Palo Alto, California; 278 pp.

GARCÍA MORALES, M., DENNO, B.D., MILLER, D.R., MILLER, G.L., BEN-DOV, Y. and HARDY, N.B. 2020. *ScaleNet: a literature-based model of scale insect biology and systematics.* Database. [Accessed 13 July 2020] Available from URL: http://scalenet.info

GAVRILOV-ZIMIN, I.A. and DANZIG, E.M. 2012. Taxonomic position of the genus *Puto* Signoret (Homoptera: Coccinea: Pseudococcidae) and separation of higher taxa in Coccinea. *Zoosystematica Rossica* **21:** 97–111.

GREEN, E.E. 1922. *The Coccidae of Ceylon, Part V.* Dulau & Co., London; pp. 345–472.

GULLAN, P.J. 1984. A revision of the gall-forming coccoid genus *Apiomorpha* Rübsaaman (Homoptera: Eriococcidae: Apiomorphinae). *Australian Journal of Zoology* Supplementary Series **97:** 1–203.

GULLAN, P.J. and COOK, L.G. 2007. Phylogeny and higher classification of the scale insects (Hemiptera: Sternorrhyncha: Coccoidea). *Zootaxa* **1668:** 413–425.

GULLAN, P.J., DONALDSON, S.R. and KNOX, G.A. 1987. Mealybugs (Coccoidea: Pseudococcidae) from the Australian National Botanic Gardens, Canberra. *Australian entomological Magazine* **14:** 49–53.

GULLAN, P.J., MOIR, M.L. and LENG, M.C. 2013. A new species of mealybug (Hemiptera: Pseudococcidae) from critically endangered *Banksia montana* in Western Australia. *Records of the Western Australian Museum* **28:** 12–20.

HARDY, N.B., GULLAN, P.J. and HODGSON, C.J. 2008. A subfamily-level classification of mealybugs (Hemiptera: Pseudococcidae) based on integrated molecular and morphological data. *Systematic Entomology* **33:** 51–71.

HODGSON, C.J. and FOLDI, I. 2006. A review of the Margarodidae *sensu* Morrison (Hemiptera: Coccoidea) and some related taxa based on the morphology of adult males. *Zootaxa* **1263:** 1–250.

KAYDAN, M.B., KOZÁR, F. and HODGSON, C.J. 2015. A review of the phylogeny of Palaearctic mealybugs (Hemiptera: Coccomorpha: Pseudococcidae). *Arthropod Systematics & Phylogeny* **73:** 175–195.

KOSZTARAB, M. and KOZÁR, F. 1988. *Scale insects of Central Europe.* Dr A.W. Junk Publishers, Dordrecht, The Netherlands, and Akadémiai Kiadó, Budapest, Hungary; 456 pp.

KOTEJA, J. 1980. Campaniform, basiconic, coeloconic, and intersegmental sensilla on the antennae in the Coccinea (Homoptera). *Acta Biologica Cracoviensia* **22:** 73–88.

MAMET, R. 1942a. New pseudococcids from Mauritius (Homoptera, Coccoidea). *Proceedings of the Royal Entomological Society of London, Series B* **11:** 79–86.

MAMET, R. 1942b. *Pedronia strobilanthis* Green redescribed (Homoptera, Coccoidea: Pseudococcidae). *Proceedings of the Royal Entomological Society of London, Series B* **11:** 149–152.

MAROTTA, S. and TRANFAGLIA, A. 1993. Le specie del genere *Puto* Signoret (Homoptera Coccoidea Pseudococcidae) dell Europa centrale e del bacino del Mediterraneo. *Bollettino del Laboratorio di Entomologia Agraria "Filippo Silvestri"* **48:** 171–205.

MASKELL, W.M. 1893. Further coccid notes: with descriptions of new species from Australia, India, Sandwich Islands, Demerara, and South Pacific. *Transactions and Proceedings of the New Zealand Institute* **25 (1892):** 201–252.

MOIR, M.L. 2020. Coextinction of *Pseudococcus markharveyi* (Hemiptera: Pseudococcidae): a case study in the modern insect extinction crisis. *Austral Entomology*, Version of Record 15 November 2020, doi: 10.1111/aen.12506

QIN, T.K. and GULLAN, P.J. 1990. The Australian mealybugs (Homoptera: Pseudococcidae) of *Xanthorrhoea* (Xanthorrhoeaceae). *Invertebrate Taxonomy* **3:** 759–769.

SIGNORET, V. 1876. Essai sur les cochenilles ou gallinsectes (Homoptères - Coccides), 17e partie. *Annales de la Société Entomologique de France* **5:** 374–394.

ŠULC, K. 1898. Studie o coccidech. - II. *Sitzungsberichte der K. Bohmisch Gesellschaft der Wissenschaften* (1897) **66:** 1–19.

WANG, X., XIE, Y.P., LIU, W.M., and XIONG, Q. 2018. Antennal sensilla of *Didesmococcus koreanus* Borchsenius (Hemiptera: Coccoidea: Coccidae) in different instars. *Zoologischer Anzeiger* **274:** 103–114.

WESTWOOD, J.O. 1840. *An introduction to the modern classification of insects; founded on the natural habits and corresponding organization of different families. Vol. II.* Longman, Orme, Brown, Green and Longmans, London; 587 pp.

WILLIAMS, D.J. 1985. *Australian mealybugs*. British Museum (Natural History) London; 431 pp.

WILLIAMS, D.J. 2004. *Mealybugs of southern Asia*. The Natural History Museum, London. Southdene SDN, BHD, Kuala Lumpur; 896 pp.

WILLIAMS, D.J. and GRANARA DE WILLINK, M.C. 1992. *Mealybugs of Central and South America*. CAB International, Wallingford, U.K.; 635 pp.

WILLIAMS, D.J. and WATSON, G.W. 1988. *The scale insects of the Tropical South Pacific region. Part 2. The Mealybugs (Pseudococcidae)*. C.A.B. International, Wallingford, U.K.; 260 pp.

WILLIAMS, D.J., GULLAN, P.J., MILLER, D.R., MATILE-FERRERO, D., and HAN, S.I. 2011. A study of the scale insect genera *Puto* Signoret (Hemiptera: Sternorrhyncha: Coccoidea: Putoidae) and *Ceroputo* Šulc (Pseudococcidae) with a comparison to *Phenacoccus* Cockerell (Pseudococcidae). *Zootaxa* **2802:** 1–22.

NOTES ON THE BIOLOGY, ECOLOGY, LIFE HISTORY AND CONSERVATION OF THE GRACEFUL SUN-MOTH *SYNEMON GRATIOSA* WESTWOOD, 1877 (LEPIDOPTERA: CASTNIIDAE)

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Abstract

The distribution, habitat, behaviour and life history of the graceful sun-moth *Synemon gratiosa* Westwood, 1877 was studied over a ten-year period between 2009 and 2018. The species is endemic to south-west Western Australia where it occurs in a series of disjunct subpopulations between Binningup and Kalbarri, a range of ~625km. It is mainly restricted to coastal and near-coastal sand dunes, but extends into *Banksia* L.f. woodlands near Perth. Larvae feed in the leaf bases and rhizomes of two host plants, *Lomandra maritima* T.S. Choo (on coastal dunes) and *L. hermaphrodita* (C.R.P. Andrews) C.A. Gardner (in *Banksia* woodlands). Abundance is typically low, despite the host plant being abundant, and occasionally the dominant species, at some sites. As they reach maturity the larvae damage or kill parts of the host plant, which enables them to be detected fairly readily. Details of the species biology, ecology and life history are recorded. The impact of anthropogenic land clearing and fragmentation on the conservation of *S. gratiosa* is discussed.

Keywords: Australia, sun-moth, monitoring, distribution, flight time, host-plants

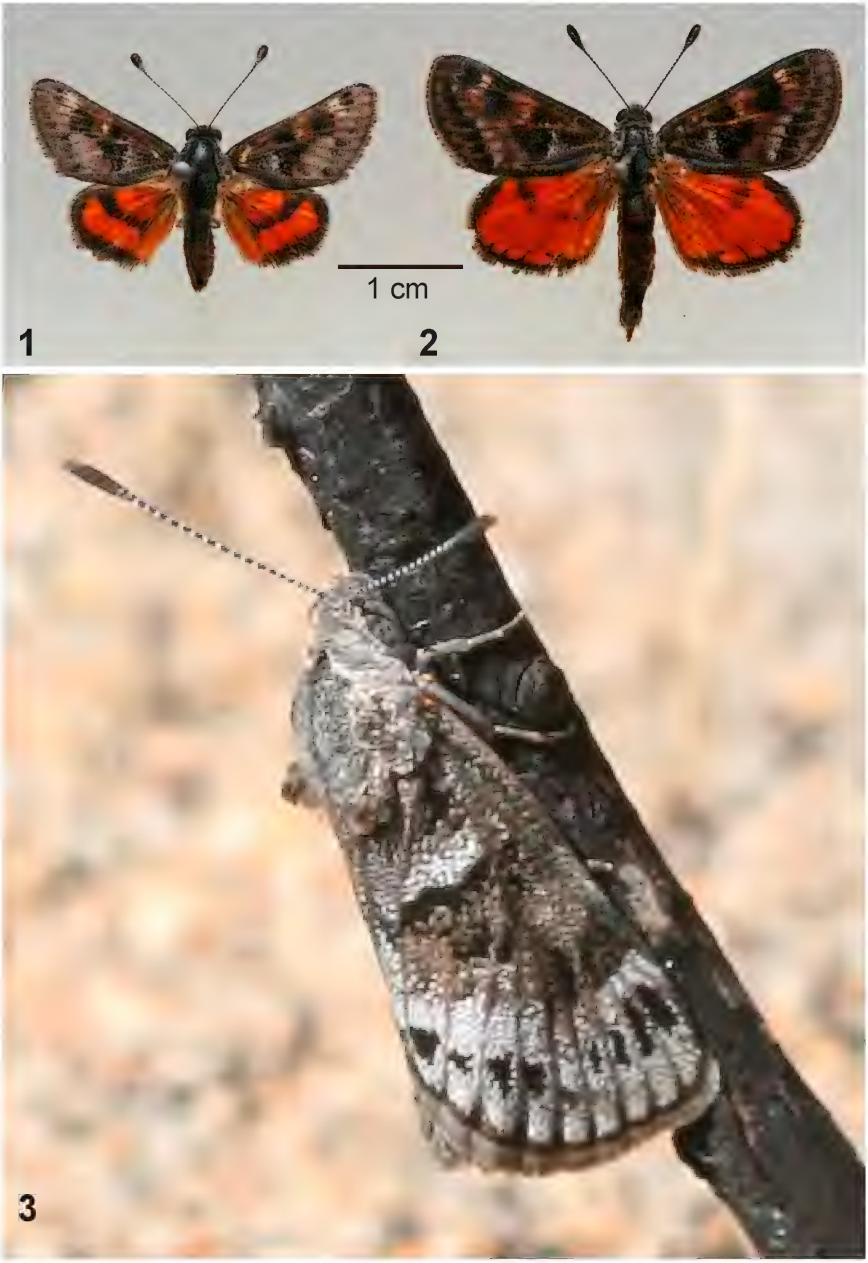
Introduction

Castniidae is a small family of day-flying moths with a Gondwanan origin (Hall and Holloway 1998). Their present distribution mirrors that of the marsupials, with around 100 species in South and Central America and 45 in Australia (Edwards 1997; Niño-Maldonado *et al.* 2013). All are diurnal, have clubbed antennae and broad, often brightly-coloured wings and closely resemble (and are often mistaken for) butterflies. The Australian species are all commonly called "sun-moths" and are classified in the genus *Synemon* Doubleday, 1846 in the tribe Synemonini (Common, 1990). Several species are of conservation concern (Clarke and O'Dwyer 2000; Clarke and Whyte 2003; Douglas 2003, 2004; Anon. 2009, 2012; Bishop *et al.* 2010; Williams *et al.* 2016). South-western Western Australia is a centre of diversity for sun-moths, with about half of the Australian species endemic to the region (Williams *et al.* 2016).

The graceful sun-moth *S. gratiosa* Westwood, 1877 was listed as a nationally threatened species under the Commonwealth of Australia EPBC Act in 2009 (Threatened Species Scientific Committee (TSSC), 2008). At that time the species was thought to be restricted to the Perth metropolitan region and to a single host plant, *Lomandra hermaphrodita* (C.R.P. Andrews) C.A. Gardner. When listed, nine extant and seven locally extinct subpopulations were identified, all within the greater Perth region. However, information on the species' distribution, life history, flight period and ecology were lacking.

There is little detailed information on the biology and ecology of most sun-moth species (Common and Edwards 1981; Douglas 2003), but the following general life history has been documented. Adult sun-moths are thought to live for approximately 4–10 days, depending on the species (Douglas and Marriott 2003), although *S. plana* Walker, 1854 has a much shorter lifespan (Richter *et al*. 2013). All species are active during daylight, and many will not fly except in bright sunshine. The adults of some species (including the graceful sun-moth) have reduced mouthparts and do not feed, relying on nutrients stored during the larval stage to sustain them through their adult lives (Common and Edwards 1981; Douglas 2003). Female sun-moths mate and commence egg-laying soon after emergence from the pupal stage, depositing eggs beneath the soil, at or near the base of their larval host plants. Fecundity of most species is unknown, but the critically endangered *S. plana* is thought to produce 100–150 eggs (Clarke and O'Dwyer 2000). After hatching, the larvae tunnel within or beside the roots, rhizomes or basal leaves of the host plant on which they feed (Common and Edwards 1981; Douglas 2003). Most sun-moth species are consistently associated with either one or occasionally two species of host plants (Douglas 2003). It is generally not known how long sun-moths take to complete their life cycles, but *S. magnifica* Strand, 1911 is known to take two to three years to complete development, and *S. jcaria* R. Felder, 1874, thought to be the closest relative of the graceful sun moth, may have a two year life-cycle (Common and Edwards 1981; E.D. Edwards ANIC *pers. comm*.; M.R. Williams, A.A.E. Williams and N. Willers WA DEC, *pers. obs*.). Like many butterflies, male graceful sun-moths may seek out sandy hilltops or the ridges of dunes, where they hold territories, but always where their larval food-plants are growing. When disturbed, males will fly away but rarely leave the vicinity. During the adult phase, the moths mate and the females then spend most of their time laying eggs. Because of their behavioural differences, males are usually encountered more frequently during surveys, although the sex ratio is thought to be 1:1. After mating, female graceful sun moths generally avoid males and will usually be found where *Lomandra* Labill. food plants occur away from hilltops or ridges. Typically, it is the requirements of the immature stages that define habitat quality for insects, and the importance of host plant density for butterflies and day-flying moths has been widely demonstrated (Williams 2011). Therefore, the distribution of the host plant is an important determinant of the potential habitat.

The main identified threats to the graceful sun-moth are clearing of habitat for urban, rural and industrial development, particularly in the greater Perth to Peel urban region, and inappropriate management of habitat. Several sites are known to have been lost because of land clearing. Several large, uncleared sites where the graceful sun moth has been recorded in the past are no longer occupied (e.g. Kings Park, Bold Park, Whiteman Park and Neerabup), and it is thought that past management practices (inappropriate fire regimes, weed invasion and grazing) have contributed to these local extinctions.



Figs 1–3. Adults of *Synemon gratiosa*: set specimens of (1) male (Binningup, WA); (2) female (Amstel Park, Perth, WA); and (3) adult female in vivo. Photos: Andrew Williams.

Over the ten-year period 2009–2018 we conducted a research program to determine the distribution, regional abundance and conservation status of *S. gratiosa*. As a result, many details of the biology and ecology of the species have now been recorded that are relevant to its ongoing conservation, as well as to the conservation of other sun-moths, Castniidae, and moths generally.

Methods

Study species. Synemon gratiosa (Figs 1–3) is the smallest species of sun-moth, with a wingspan of 20–33 mm (Williams *et al.* 2016). Males (20–27 mm, average 25 mm) are generally smaller than females (26–33 mm, average 30 mm). The upper side of the forewings is brownish grey, variously patterned with areas of silvery grey scales and black markings. In contrast, the upper side of the hind wing is orange with a blackish border and highly variable (sometimes absent) blackish median band. The forewing upper sides are cryptically patterned and when at rest adults adopt a characteristic resting posture with the forewings obscuring the brightly coloured hind wings (Fig. 3). This habit makes resting adults difficult to detect.

Sampling. Synemon gratiosa was the subject of targeted searches for occupied habitat and a transect-based monitoring project between 2009 and 2018. Transect surveys were conducted during the flight period each year by volunteers, development proponents, and staff of the Department of Biodiversity, Conservation and Attractions (and its predecessor organisations). Each survey followed a protocol designed to maximise the likelihood of detecting *S. gratiosa*, if present, at a site (Bishop *et al.* 2010) and were usually conducted in weather conditions suitable for sampling diurnal Lepidoptera in south-western Australia—i.e. days with a forecast maximum temperature above 23°C and little cloud cover (Williams 2009). As the species is often uncommon and difficult to detect, it is necessary to survey sites several times in suitable weather conditions to determine if it is present (Williams 2009; Bishop *et al.* 2010). A mark-recapture study was also conducted in 2016 and 2017 (Williams *et al.* 2018). As well as recording all *S. gratiosa* individuals detected during the surveys, observations relevant to the life history or ecology of the species (copulation, ovipositing, territorial behaviour, predation, etc.) were recorded.

Life History

Oviposition. Mated females seek out suitable larval food-plants on which to oviposit (Gamblin *et al.* 2011). When selected, the female walks backwards down to the leaf bases where a single egg is inserted below ground alongside the leaf base. Laboratory dissections of five freshly emerged, female *S. gratiosa* have shown that they carry 29–32 eggs, with an average of 30. Adults do not possess functional mouthparts and do not feed, so this likely represents their total potential fecundity.

Egg (Fig. 4). Height 2.3–2.5 mm, width 0.9–1.1 mm. Cream-white in colour, spindle-shaped and bluntly pointed at each end. Several prominent longitudinal

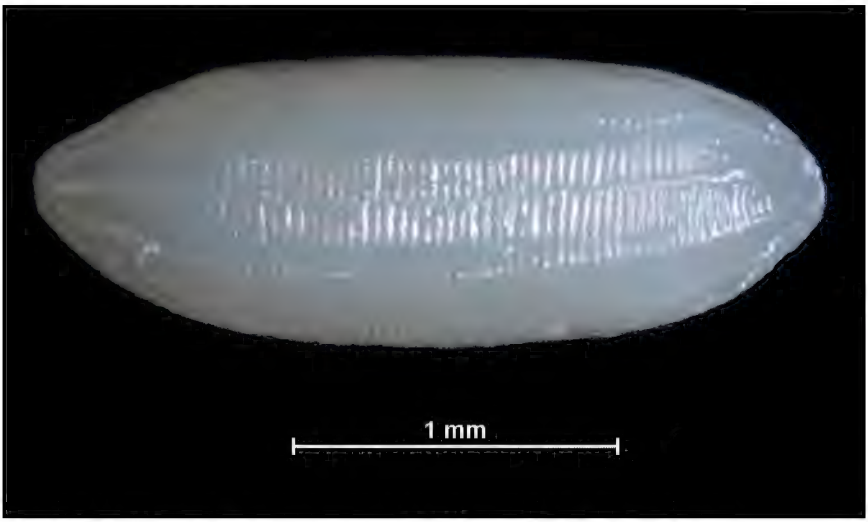


Fig. 4. Egg of *Synemon gratiosa*, excised from female. Photo: Adrian Pinder.

ridges (usually 10–12) converge at each end. The surface has approximately ~75 very fine transverse striae.

Mature larva (Figs 5–7). Length 18–21 mm, cylindrical in shape, slightly tapered towards the posterior end. The body is cream-white in colour with a narrow blackish mid-dorsal line, most visible on the first two abdominal segments (but not visible in specimens preserved in ethanol). It has clearly-defined thoracic and abdominal segments. The small dark brown head capsule with the associated mouthparts and adfrontal area are almost enveloped by a very large, bulbous, partially sclerotized yellow-brown prothorax. The three thoracic segments each possess a pair of very short segmented legs, each tipped with a brown apical claw. An oval spiracle is located on each side of the prothorax and on the sides of eight abdominal segments. The first seven abdominal segments each have fleshy dorso-lateral rounded projections. The underside ventral area has four moderately developed fleshy abdominal prolegs, each with a group of three or four tiny black crochets. The terminal segment has a pair of anal prolegs. There are a few extraordinarily fine, moderately long, colourless setae located along the mid-portion of the body which are only visible under suitable lighting conditions. Stiffer, pointed setae are also present round the head and mouthparts, on the segmented thoracic legs, and on the anal segment.

As larvae approach maturity, their feeding often leads to characteristic yellowing or death of leaves on otherwise healthy plants, thus enabling the larva to be located (Fig. 8). We excavated many plants and often found both mature and immature larvae at the same site or in the same plant, often during the flight period—suggesting a likely two or three-year life cycle. When mature, the larva

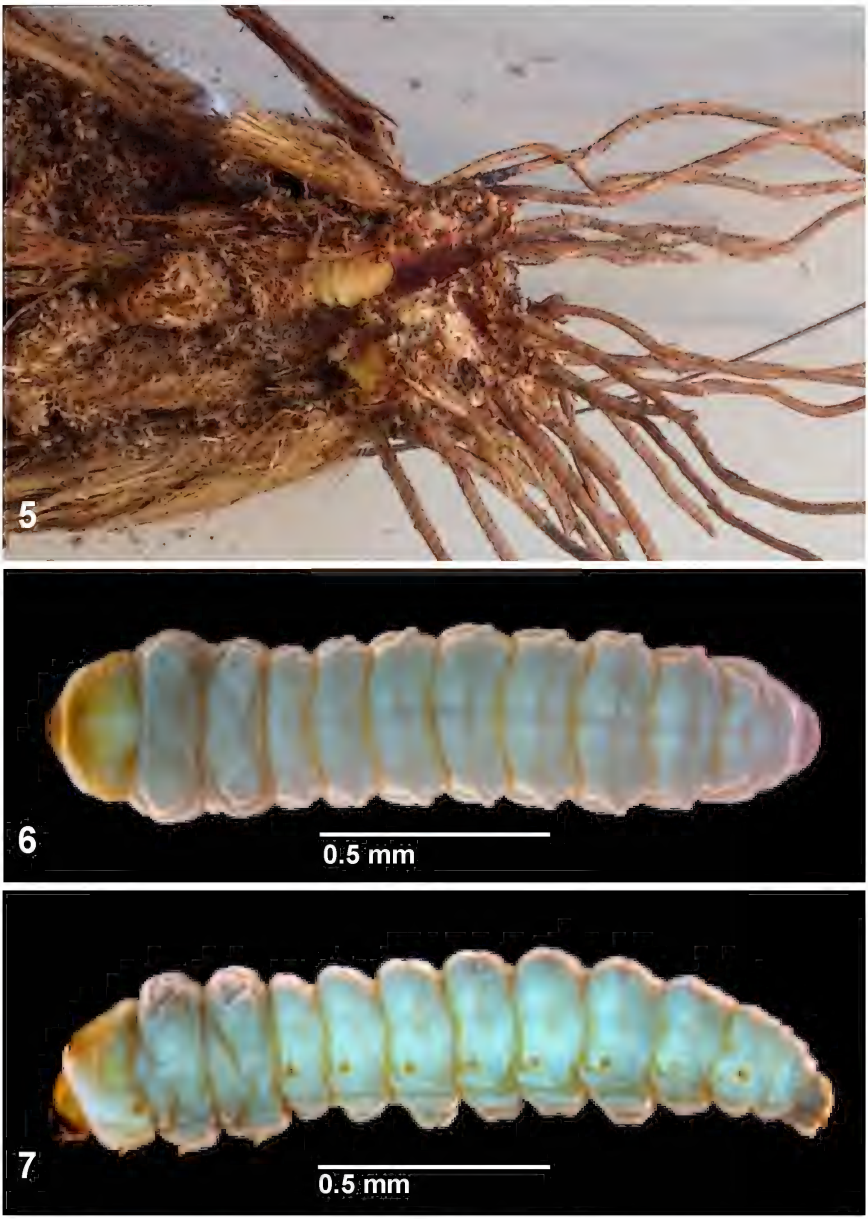
pupates inside a vertical, open-ended silk tube constructed within or beside the food-plant's leaf bases, with the pupal head uppermost. The pupa is mobile, and able to move within the silk tube. Once the adult has emerged, the empty pupal case remains partially exposed.

Pupa (Figs 9–11). Length 15–17 mm; cylindrical, with a rounded head, the abdomen narrowing to a bluntly pointed posterior. The wing cases reach to the mid-point of the pupa. Thorax smooth with a slightly raised central dorsal ridge. Seven abdominal segments are partially ringed (dorso-laterally) with backward-pointing saw-like teeth; these are absent on the ventral surface. The eye is dark, large and rounded. Pupae *in vivo* are dark brown in colour. The exuviae (Figs 10, 11) retain the same external features as the pupa and their brown colouration.

Flight period. Adults were recorded from mid-February until the first week in April.

Adult variation. There is considerable phenotypic variation within *S. gratiosa*. Specimens from the southernmost subpopulation, at Binningup, have a very pronounced black band on the termen of the hindwing and a prominent medial band in both males and females. Further north, the hindwing markings of *S. gratiosa* are less prominent, but variable: some individuals lack both hindwing bands and considerable variation in these bands is apparent even within a single site. Specimens from *Banksia* L.f. woodlands on the Swan Coastal Plain east of Perth have noticeably darker upper forewings and are also more extensively orange below than those from coastal sites. Specimens from the northernmost subpopulation, at Murchison House Station on the northern bank of the Murchison River adjacent to Kalbarri, have mostly uniform orange hindwings, though some have narrow medial and marginal black bands. The reasons for this variation between the northern and southern extremities of the species' range are not understood, but may relate to the temperature regime experienced by the larval or pupal stages.

Behaviour. Adults are active in warm to hot, sunny conditions, generally between 09:30 and 15:00 hours Western Standard Time. Adults are very rarely disturbed from their resting locations outside of these times or when conditions are unsuitable. In coastal and near-coastal sites, males establish small territories that are about 20 m^2 in extent on upper dune slopes, ridges or dune crests, always in the vicinity of the *L. maritima* T.S. Choo host plants (Williams *et al.* 2016). Typically, males fly close to the ground but only for short periods before settling on a low stick, plant stem or on the ground. Coastal sites are often windy, and in such conditions males may occupy the more sheltered lee side of a dune. In extremely windy conditions, individuals have been observed taking shelter on stems of low shrubs or on the ground. In the more sheltered *Banksia* woodlands on the Swan Coastal Plain, males typically occupy areas of bare sand, which may be either naturally occurring, on firebreaks or walking tracks. Here they establish territories, always in close proximity to *L. hermaphrodita* plants.



Figs 5–7. *Synemon gratiosa* mature larva. (5) Partially exposed mature larva within its feeding tunnel in the subterranean parts of *Lomandra hermaphrodita*. The tunnel extends from the leaf bases into the rhizome. Photo: Andrew Williams. (6, 7) Dorsal and lateral views, respectively. Photos: Adrian Pinder.

In both coastal and *Banksia* woodland sites, females are less frequently encountered. This appears to be an observation bias, as males are typically sedentary and occupy locations convenient for walking, whereas females are dispersed more broadly through the habitat. When an unmated female enters a male's territory, the male will immediately abandon his territory and pursue the female until she lands, at which time copulation may take place (Williams *et al.* 2016). At Port Denison, south of Geraldton, a copulating pair of *S. gratiosa* was observed in flight in 2017—the only instance of copulation observed during the nine year study. The larger female carried the smaller male (M.R. Williams, *pers. obs.*).

On several occasions we observed dragonflies predating *S. gratiosa* and consider these to be the sun-moth's primary predator.

Larval food-plants. The main larval food-plant is *Lomandra maritima*, which has been recorded on coastal and near-coastal dunes and adjacent areas between Binningup and Shark Bay (Fig. 12). The typical habitat of *L. maritima* is the ridges and slopes of parabolic dunes in the Quindalup Dune system (Semniuk *et al.* 1989), but it may also extend into swales and other areas nearby. These dunes are typically within one or two kilometres of the coast, but in several places extend up to 5 km inland, and at Wanagarren up to 15 km inland. The larval food-plant in *Banksia* woodlands near Perth is the smaller *L. hermaphrodita*. The typical habitat of *L. hermaphrodita* is *Banksia* woodlands of the Spearwood and Bassendean Dune systems, although the plant extends much more widely in south-western Australia, including into jarrah (*Eucalyptus marginata* Donn ex Sm.) forest on the Darling Scarp.

Distribution and habitat. Synemon gratiosa has been recorded at more than 80 locations between Binningup (33.2°S), 20 km north of Bunbury, to Kalbarri and the adjacent Murchison House Station on the north side of the Murchison river (27.7°S) (Fig. 13), a distance of ~625 km (TSSC 2013; Williams *et al.* 2016). The vast majority of remaining habitat occurs on the coastal dunes within a few km of the coast. Despite targeted surveys and searches for early stages, *S. gratiosa* was not recorded from apparently suitable habitat on near-coastal dunes near Shark Bay, where *L. maritima* is locally abundant and the dominant plant in many areas. It is also absent from Rottnest Island, where suitable sand dunes occur, but *L. maritima* does not occur on the island. It has an extensive but disjunct near-coastal distribution, only occurring more than several kms inland on the Swan Coastal Plain near Perth. Although the overall extent of occurrence is large, suitable habitat is primarily restricted to a narrow corridor of coastal dunes. These dunes form large, continuous patches of habitat in some places, but are fragmented elsewhere—as a result of both naturally-occurring areas of unsuitable landforms, as well as clearing for rural and urban development since European settlement. Across its geographic range, the graceful sun-moth shows low to moderate levels of genetic diversity (unpubl. data), with no differentiation between populations in the coastal heathland, which feed on *L. maritima*, and populations in the *Banksia* woodlands of the Swan Coastal Plain, where larvae feed on *L. hermaphrodita*.

Fig. 8. The yellow-brown, freshly dying leaves on this *Lomandra maritima* plant indicate the likely presence of a *Synemon gratiosa* larva in the rhizome below. Photo: Carly Bishop.

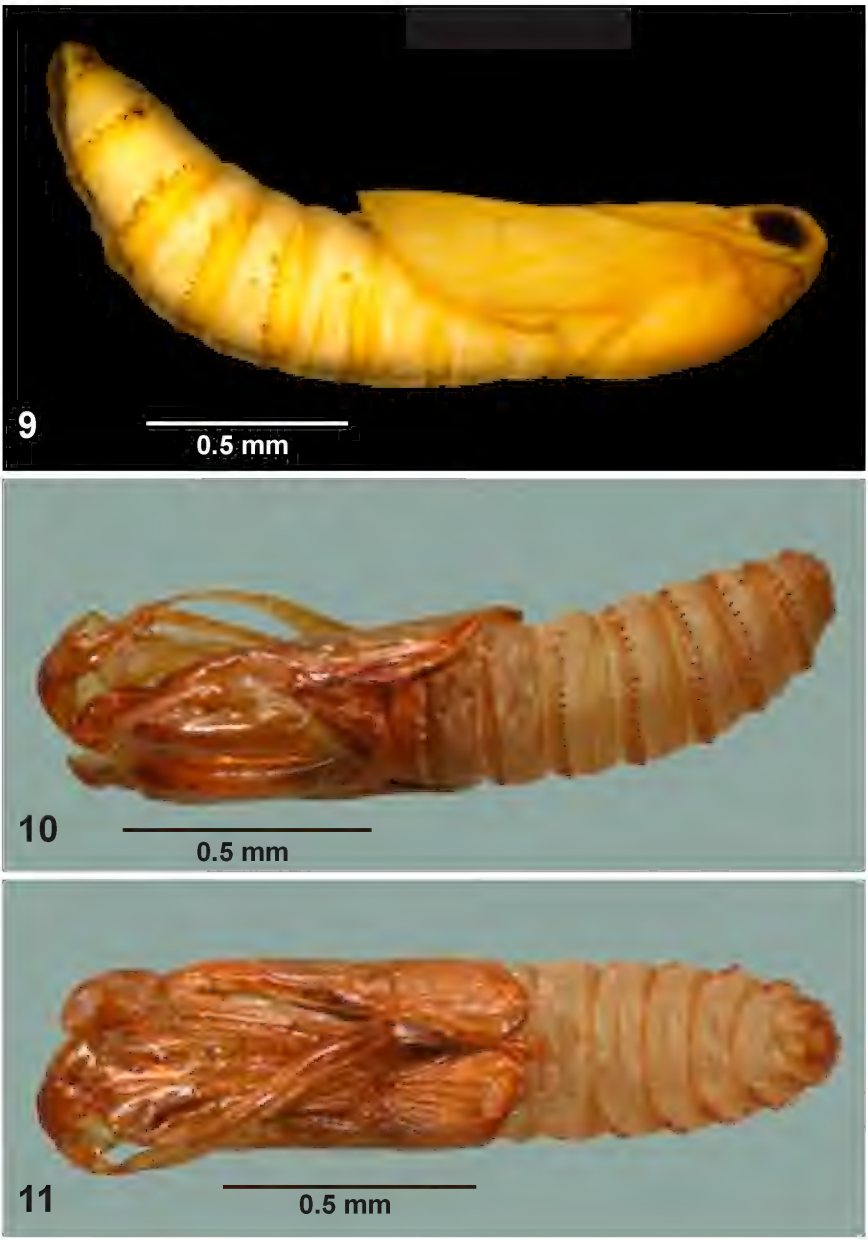
In the coastal dune habitat between Binningup and Kalbarri, four regions were identified as being particularly important for graceful sun-moth conservation (Bishop *et al.* 2010; Williams *et al.* 2012). These have high population density (based on transect counts of adults and density of host plants), contain large areas of contiguous habitat in good condition, and are representative of genetic variation within the species. These regions are (1) Yalgorup National Park and adjacent areas to the south (Myalup to Binningup); (2) the northern Perth suburbs of Alkimos, Eglinton and Yanchep; (3) Wanagarren and Nilgen nature reserves; and (4) the disjunct populations between Coolimba and Kalbarri. Populations of *S. gratiosa* occur in several small remnants of coastal dune habitat near Perth that are now completely isolated by urbanisation. These include Cawarra Bushland in Craigie (3.9 ha), Madana Park in Craigie (1.0 ha) and Maritana Bushland in Kallaroo (2.5 ha). In *Banksia* woodland habitat on the Swan Coastal Plain, *S. gratiosa* has been recorded from fewer than 15 patches of remnant habitat.

The graceful sun-moth has been recorded in coastal sites with average *Lomandra maritima* density ranging from 5–30% cover. In these sites *L. maritima* may form a dominant herbland (TSSC 2013). In comparison, *L. hermaphrodita* is found across a range of vegetation communities (*Banksia* woodland, jarrah woodland, tuart woodland, etc.) but is never a dominant component and has much lower density, cover and biomass compared to *L. maritima* (Bishop *et al.* 2010). The graceful sun-moth has been recorded in sites with *L. hermaphrodita* density ranging from 0.2–0.8 plants/m^2.

Discussion

Surveys conducted over the period 2009–2018 have resulted in the discovery of a number of previously unknown *S. gratiosa* populations and substantially extended the known range of this species. In addition to previously documented loss of subpopulations, several more subpopulations have recently been lost due to habitat clearing for urban development, primarily in the Perth suburbs including a large loss of habitat in the Alkimos, Eglinton and Yanchep area. It is projected that by 2022 at least 18% of the species' habitat will have been lost, based on projected land clearing in its coastal habitat (TSSC 2013). It is possible that the range may be more extensive, with two areas relatively poorly sampled: between the Murchison river mouth at Kalbarri and the extensive sand dunes around Shark Bay; and the *Banksia* woodlands north and south of Perth, between Jurien Bay and Dunsborough.

The life cycle of *S. gratiosa* is generally similar to that recorded for other sun-moth species. *Synemon gratiosa* belongs to the *S. laeta* Walker, 1854 species group, which comprises four species: *S. edwardsi* Williams and Williams 2016, *S. gratiosa* (both endemic to south-western Western Australia), *S. jcaria* (occurring from south-western to eastern Australia) and *S. laeta* (from northern NSW and Queensland) (Murphy 2015; E.D. Edwards, *pers. comm.*; Williams and Williams 2016; Williams *et al.* 2016). This group of species breed on Asparagaceae, either



Figs 9–11. *Synemon gratiosa* pupa. (9) Lateral view of specimen preserved in ethanol. Photo: Adrian Pinder. (10, 11) Pupal exuvium, dorso-lateral and ventral views, respectively. Photos: Andrew Williams.

Fig. 12. A near-coastal dune in Wanagarren Nature Reserve, typical habitat of *Synemon gratiosa*. The larval foodplant, *Lomandra maritima*, is common on this dune but also occurs, at lower densities, in the inter-dunal swales. Photo: Andrew Williams.

Lomandra Labill. or the closely-related *Chamaexeros* Benth. *Synemon edwardsi* has been recorded in November, whereas the other three species fly in summer and autumn.

Synemon gratiosa still persists in several small reserves that are now isolated remnants of the original coastal dunes. Some of these remnants still have densities of *L. maritima* sufficient to support small colonies of graceful sun-moths (Bishop *et al*. 2010; Williams *et al*. 2018) but how long these subpopulations can persist in these small isolated remnants is uncertain.

The largest expanse of protected *S. gratiosa* habitat is in Nilgen and Wanagarren Nature Reserves (Williams *et al*. 2012). If the intervening but unsurveyed Lancelin Training Area (under the control of the Federal Department of Defence) is occupied by *S. gratiosa*, then this region comprises the most important area for preservation and conservation of *S. gratiosa*. South of Perth, Yalgorup National Park also contains a sizable area of coastal dune habitat. The only place where *S. gratiosa* is known to occur inland from the coast is on the Swan Coastal Plain around Perth. Before European settlement, the *Banksia*-dominated woodlands on the plain would have supported a large and near-continuous *S. gratiosa* population. However, extensive past land clearing means that *S. gratiosa* now survives only in a relatively few *Banksia* woodland reserves.

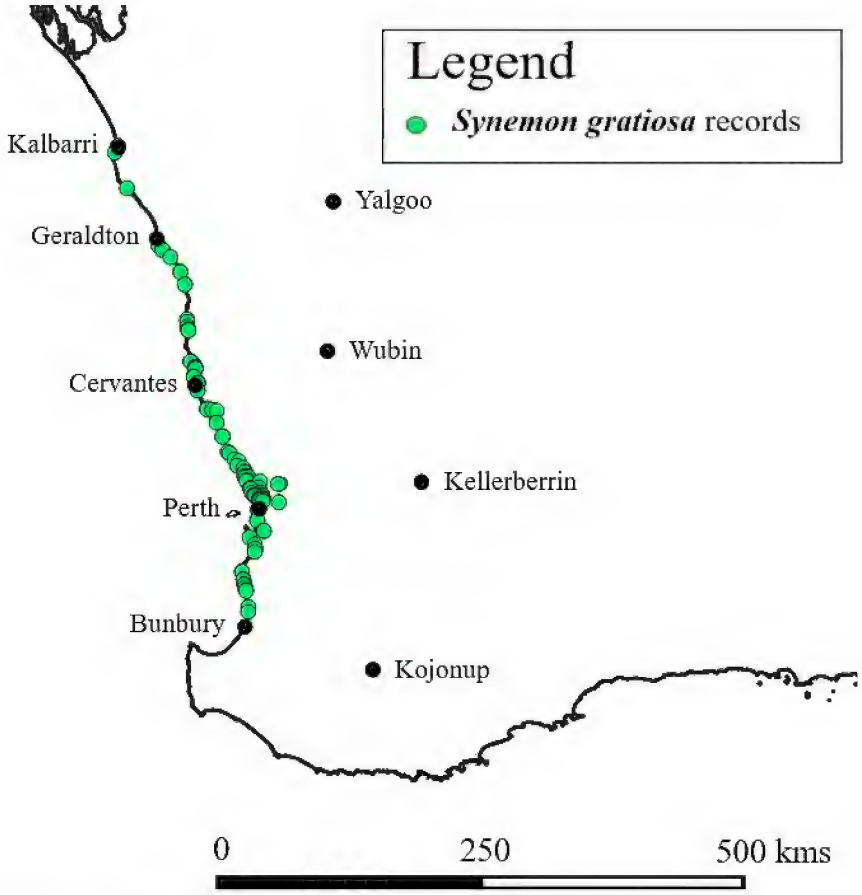


Fig. 13. Distribution of *Synemon gratiosa* from Binningup in the south to Murchison House Station immediately north of Kalbarri in the north

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References

ANONYMOUS 2009. EPBC Act. List of threatened fauna. Department of Sustainability, Environment, Water, Populations and Communities. Canberra, ACT.

ANONYMOUS 2012. *Synemon plana* species profile and threats database. Department of Sustainability, Environment, Water, Populations and Communities. Canberra, ACT. Available from: http://www.environment.gov.au/sprat (downloaded March 2020).

BISHOP, C., WILLIAMS, M., MITCHELL, D., WILLIAMS, A., FISSOLI, J. and GAMBLIN, T. 2010. *Conservation of the graceful sun-moth (*Synemon gratiosa*): findings from the 2010 graceful sun-moth surveys and habitat assessments across the Swan, South-West and southern Midwest regions: Interim report, August 2010.* Department of Environment and Conservation, Kensington, WA; 30 pp.

CLARKE, G.M. and O'DWYER, C. 2000. Genetic variability and population structure of the endangered golden sun moth, *Synemon plana*. *Biological Conservation* **92:** 371–381.

CLARKE, G.M. and WHYTE, L.S. 2003. Phylogeography and population history of the endangered golden sun moth (*Synemon plana*) revealed by allozymes and mitochondrial DNA analysis. *Conservation Genetics* **4:** 719–734.

COMMON, I.F.B. 1990. *Moths of Australia*. Melbourne University Press, Carlton, Vic.; vi + 535 pp.

COMMN, I.F.B. and EDWARDS, E.D. 1981. The life history and early stages of *Synemon magnifica* Strand (Lepidoptera: Castniidae). *Journal of the Australian Entomological Society* **20:** 295–302.

DOUBLEDAY, E. 1846. Descriptions of some New or Imperfectly characterised Lepidoptera from Australia (Appendix pp 513-520, pl. 3). In: Stokes, J.L., *Discoveries in Australia; with an Account of the Coasts and Rivers Explored and Surveyed during the Voyage of H.M.S. Beagle, in the Years 1837-1843. Vol. 1.* T. & W. Boon, London; 521 pp.

DOUGLAS, F. 2003. Five threatened Victorian Sunmoths (*Synemon* species). Flora and Fauna Guarantee Act Action Statement 146, p. 11. Department of Sustainability and Environment, Melbourne, Victoria.

DOUGLAS, F. 2004. A dedicated reserve for conservation of two species of *Synemon* (Lepidoptera: Castniidae) in Australia. *Journal of Insect Conservation* **8:** 221–228.

DOUGLAS, F. and MARRIOTT, P. 2003. Some notes on the sun-moths, Lepidoptera: Castniidae. *Victorian Entomologist* **33:** 90–97.

EDWARDS, E.D. 1997. Moths in the sun. *ANIC News* 10, April 1997.

FELDER, R. 1874. 'S. Icaria' *In*: Histoire naturelle des insects. Species général des lépidoptères héterocères (Eds.), JA Boisduval and A Guenée, *Librarie encyclopedique de Roret*, Paris, pp 554–555.

GAMBLIN, T., BISHOP, C., WILLIAMS, M. and WILLIAMS, A. 2011. Graceful sun-moth (*Synemon gratiosa*). Information Sheet 41, 2 pp. Available at: http://www.dpaw.wa.gov.au/about-us/science-and-research/publications-resources/111-science-division-information-sheets/.

HALL, R. and HOLLOWAY, J.D. 1998. *Biogeography and geological evolution of SE Asia.* Backhuys, Leiden; 417 pp.

MURPHY, M.J. 2015. First records of the sun moth *Synemon laeta* Walker, 1854 (Lepidoptera: Castniidae) from New South Wales. *Victorian Naturalist* **132:** 44:48.

NIÑO-MALDOADO, S., DE LEÓN GONZÁLEZ, E.I., MILLER, J.Y. and SÁNCHEZ REYES, U.J. 2013. New records of Castniidae (Lepidoptera) from Queretaro and Tamaulipas, Mexico. *Acta Zoologica Mexicana* **29:** 452–453.

SEMENIUK, V., CRESSWELL, I. and WURM, P.A.S. 1989. The Quindalup Dunes: the regional system, physical framework and vegetation habitats. *Journal of the Royal Society of Western Australia* **71:** 23–47.

STRAND, E. 1911. Castniidae. In: Seitz, A. (Ed.), *The Macrolepidoptera of the World. 10. Bombyces and Sphinges of the Indo-Australian Region*. 2 vols. Alfred Kernen, Stuttgart, 909 pp, 100 pls. (English Version).

THREATENED SPECIES SCIENTIFIC COMMITTEE (TSSC). 2008. Commonwealth Conservation Advice on *Synemon gratiosa*. Department of the Environment, Water, Heritage and the Arts, Canberra.

THREATENED SPECIES SCIENTIFIC COMMITTEE (TSSC). 2013. Advice to the Minister for Sustainability, E., Water, Population and Communities from the Threatened Species Scientific Committee (the Committee) on amendment to the list of Threatened Species under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/66757-listing-advice.pdf

WALKER, F. 1854. *List of the specimens of lepidopterous insects in the collection of the British Museum. Part 1, Lepidoptera Heterocera*. British Museum Trustees, London; 278 pp.

WESTWOOD, J.O. 1877. A monograph of the lepidopterous genus *Castnia* and some allied groups. *Transactions of the Linnean Society of London, Series 2, Zoology* **1:** 155–207.

WILLIAMS, A.A.E., COPPEN, R.A.M. and WILLIAMS, M.R. 2018. A method for conducting mark-release-recapture studies of the graceful sun-moth *Synemon gratiosa* (Lepidoptera: Castniidae). *Records of the Western Australian Museum* **31:** 181–186.

WILLIAMS, A.A.E. and WILLIAMS, M.R. 2016. A new species of *Synemon* Doubleday (Lepidoptera: Castniidae) from Western Australia. *Australian Entomologist* **43:** 119–134.

WILLIAMS, A.A.E., WILLIAMS, M.R., EDWARDS, E.D. and COPPEN, R.A.M. 2016. The sun-moths (Lepidoptera: Castniidae) of Western Australia: an inventory of distribution, larval food plants, habitat, behaviour, seasonality and conservation status. *Records of the Western Australian Museum* **31:** 90–162.

WILLIAMS, M.R. 2008. Assessing biodiversity of diurnal Lepidoptera in habitat fragments: testing the efficiency of strip transects. *Environmental Entomology* **37:** 1313–1322.

WILLIAMS, M.R. 2009. Butterflies and day-flying moths in a fragmented urban landscape, south-west Western Australia: patterns of species richness. *Pacific Conservation Biology* **15:** 32–46.

WILLIAMS, M.R. 2011. Habitat resources, remnant vegetation condition and area determine distribution patterns and abundance of butterflies and day-flying moths in a fragmented urban landscape, south-west Western Australia. *Journal of Insect Conservation* **15:** 37–54.

WILLIAMS, M., BISHOP, C., MITCHELL, D., WILLIAMS, A. and GAMBLIN, T. 2012. *Conservation of the graceful sun-moth (*Synemon gratiosa*): survey results from the Swan, South West and southern Midwest regions 2010–2012: summary report*. Department of Environment and Conservation, Kensington, WA; 16 pp.

NOTES ON THE GENUS *MYOTYPHLUS* FAUVEL, 1883 (COLEOPTERA: STAPHYLINIDAE) IN TASMANIA

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Abstract

Based on a rare, large sample of *Myotyphlus* Fauvel, 1883 from Tasmania, *Myotyphlus newtoni* Solodovnikov and Jenkins Shaw 2017 is newly recorded for the island. A single female specimen undetermined to species level is reported from the Near Threatened *Mastacomys fuscus* Thomas, 1882 (Rodentia: Muridae), which is reported as a host for *Myotyphlus* for the first time. New records for *Myotyphlus jansoni* (Matthews, 1878) and further instances of these beetles grasping onto their host's fur with their mandibles are also reported, corroborating the hypothesis and earlier evidence that *Myotyohlus* grasp onto the fur of the mammal host to gain access to its nest or burrow. *Anotylus cribriceps* (Fauvel, 1878) and *Oxytelus collaris* Erichson, 1840 (Staphylinidae: Oxytelinae) are reported in a possibly loose association with the mammals used by *Myotyphlus* as hosts. Presumably, these oxyteline rove beetles feed on dung or decaying plant matter in the mammal nests or burrows.

Keywords: Mutualism, rodents, *Mastacomys*, rove beetles, Tasmania, new records

Introduction

The late rove beetle specialist James Stephen "Steve" Ashe accumulated extensive material of the staphylinid tribe Amblyopinini, in particular those genera and species which are associated with mammals in the Neotropics and Australia. His papers on these beetles, which were published in collaboration with Robert M. Timm, remain the go-to literature regarding the remarkable mutualism between rove beetles and mammals in the Neotropics. During a recent visit to the Snow Entomology Collection in Kansas (SEMC) my colleagues Alexey Solodovnikov and Aslak Kappel Hansen discovered a box of unmounted *Myotyphlus* Fauvel, 1883 from Tasmania, the material borrowed by Steve from the Queen Victoria Museum and Art Gallery, Launceston, Tasmania. They kindly borrowed that box from SEMC on my behalf.

In two recent papers we summarized the current knowledge of *Myotyphlus*, including the description of two new species (Solodovnikov and Jenkins Shaw 2017) and new mammalian host records for *Myotyphlus newtoni* Solodovnikov and Jenkins Shaw, 2017 (Jenkins Shaw et al. 2017). In the latter paper, we also provided the first evidence that *Myotyphlus*, like its Neotropical relatives, uses its mandibles to grasp on the fur of its mammal hosts. In the molecular phylogeny of Jenkins Shaw et al. (2020), *Myotyphlus* was recovered as sister to a group of Australian '*Quedius*' which are free-living predatory rove beetles occurring in leaf litter, fungi and other terrestrial habitats.

Based on a comparatively large sample from Tasmania from the mentioned box from SEMC, I am here reporting new information on the natural history of *Myotyphlus* species.

Materials and methods

All specimens are deposited at the Queen Victoria Museum and Art Gallery, Launceston, Tasmania (QVMAG) from where they were originally borrowed by the late Steve Ashe to SEMC. Specimens were studied using Leica MZ APO and Leica M205C stereomicroscopes. Photographs were taken using a Canon EOS 6D attached to a Leica M205C stereomicroscope. Images were stacked using Zerene Stacker v. 1.04. Dissected terminal segments of the abdomen and aedeagus were stored in glycerin in small plastic vials pinned under the respective specimens or glued to the card with the specimen.

Results

In total, 118 specimens of *Myotyphlus* were examined. Where morphologically identical males and females were collected at the same collecting event (i.e. had the same data label), they were assumed to be conspecific. In cases where females were collected without males, they were left unidentified to species level because, as we know from the previous study (Solodovnikov and Jenkins Shaw 2017), the inter-specific differences in this genus are distinct in the subtle details of the shape of the aedeagus only. Unfortunately, no precise data is provided with the specimens. However, given that mammal names are provided on all labels and given current knowledge of the genus, I assume that the beetles were taken directly from the mammal host's body or from nests identified as belonging to those mammal species. Within the sample, 45 specimens are *Myotyphlus jansoni* (Matthews, 1878) (19 males, 26 females), 65 specimens are *M. newtoni* (28 males, 37 females) and 8 specimens were not identified to species level because they were isolated females or in one case the abdominal tip was missing. Three specimens of *M. newtoni* were found to be grasping strands of hair presumably belonging to *Rattus lutreolus* (Gray, 1841) based on associated label data (Figs 1-2). 114 specimens comprising *M. jansoni* and *M. newtoni* were collected from *Rattus lutreolus*, 3 specimens of *M. jansoni* were collected from *Pseudomys higginsi* (Trouessart, 1897) and one unidentified specimen was collected from *Mastacomys fuscus* which represents a new host record for *Myotyphlus*. In addition to the specimens of *Myotyphlus*, several specimens from the rove beetle subfamily Oxytelinae were also discovered in the samples and are also reported here.

Subfamily Staphylininae

Myotyphlus jansoni (Matthews, 1878)

Material examined. Australia, Tasmania. Maggs Mt.: 4♂, 3♀, 17.x.1978, R.H. Green; 1♂, 5.ix.1978, R.H. Green, *Pseudomys higginsi*; 6♂, 7♀, 16.x.1974, R.H. Green; 1♂, 17.ii.1975, R.H. Green; 2♀, 17.i.1978, R.H. Green; 1♂, 1♀, 11.iv.1978, *Pseudomys higginsi*, R.H. Green; 1♂, 4.v.1977, R.H. Green. Maggs Mt. (600 m) from an adult female *Rattus lutreolus*: 3♂, 10♀, 26.x.1977, R.H. Green. Brooks Ck, W. Coast: 2♂, 3♀.

Figs 1, 2. *Myotyphlus* spp. (1) *Myotyphlus* sp.; (2) Male *Myotyphlus newtoni* grasping onto hairs of *Rattus lutreolus* from Underwood, Tasmania.

Notes. Most specimens of *Myotyphlus jansoni* were collected from *Rattus lutreolus* with the exception of 1 male on 5.ix.1978 and 1 male and 1 female on 11.iv.1978 from *Pseudomys higginsi*. In one case, label data indicates that 3 males and 10 females were collected from a single adult female *Rattus lutreolus*.

Myotyphlus newtoni Solodovnikov and Jenkins Shaw, 2017

(Figs 1, 2)

Material examined. Australia, Tasmania. Round Hill: 21♂, 27♀, 3.x.1978, R.H. Green, *Rattus lutreolus*; 2♂, 1♀, 2.vi.1976, R.H. Green, *Rattus lutreolus*. Underwood: 4♂, 7♀, 28.x.1979. R. Hamilton, *Rattus lutreolus*. Maggs Mt.: 1♂, 3♀, 1.iii.1978, R.H. Green, *Rattus lutreolus*.

Notes. *Myotyphlus newtoni* is reported for the first time from Tasmania. All specimens were collected from *Rattus lutreolus*.

Myotyphlus sp.

Material examined. Australia: Tasmania. 1♀, Brooks Ck, W. Coast, *Mastacomys fuscus*; 1♀ Brooks Ck, W. Coast, *Rattus lutreolus*; 1♀, Maggs Mt., 26.3.75, R.H. Green, *Rattus lutreolus*; 3♀, Maggs Mt., 19.1.77, R.H. Green, *Rattus lutreolus*; 1♀, Cradle Mt., 24.4.1980, R.H. Green, *Rattus lutreolus*; 1 sex unknown (abdomen tip missing), Mt. Barrow: 820m, .ix.1983, C. Reid, *Rattus lutreolus*.

Notes. *Myotyphlus* is reported for the first time from *Mastacomys fuscus* Thomas, 1882 (Rodentia: Muridae) based on a female specimen from 'Brooks Ck, Tas, W. Coast'. Although female *Myotyphlus* are difficult to identify reliably, based on the overall size and the locality this specimen probably belongs to *Myotyphlus jansoni*.

Subfamily Oxytelinae
Anotylus cribriceps (Fauvel, 1878)

Material examined. Australia: Tasmania. Sex unknown, Brooks Ck, W. Coast, *Rattus lutreolus* 2204-2208 B96832.

Oxytelus collaris Erichson, 1840

Material examined. Australia: Tasmania. Sex unknown, Brooks Ck, W. Coast, *Rattus lutreolus* 2204-2208 B96832.

Notes. Whilst the data label associated with the two above specimens of Oxytelinae is rather ambiguous, the fact that they were obtained during the same collecting event as some *Myotyphlus* suggests these species may occur in the burrows of the mammals.

Discussion

The genus *Myotyphlus* has historically been known from very few specimens in comparison to other genera of Amblyopinini. They presumably require more targeted collecting as was probably conducted for the material from the Queen Victoria Museum and Art Gallery in Launceston, Tasmania destined to be studied by the late Steve Ashe.

Mastacomys fuscus is a herbivorous rodent that has a disjunctive distribution in south-eastern Australia (Carron et al. 1990), where it mainly occurs in subalpine habitats which experience snow cover for about four months a year (Bubela and Happold, 1993). *M. fuscus* is predominately a nocturnally active species (Bubela et al. 1991). According to the IUCN *Mastacomys fuscus* is classified as Near Threatened and Decreasing (Woinarski and Burbidge, 2016). Phylogenetically, *Mastacomys* was recently recovered nested within *Pseudomys* (Smissen and Rowe, 2018), another genus from which *Myotyphlus* has been recorded (Jenkins Shaw et al. 2017).

The presence of two species (one *Anotylus* and one *Oxytelus*) of the subfamily Oxytelinae in the sample studied suggests that they occur in the mammal burrow or nest, although no precise information is provided on the specimen labels. *Anotylus* and *Oxytelus* are known to occur in dung and decaying plant matter (Makranczy, 2006), so it seems likely that the specimens studied here were feeding on dung or other decaying matter in the burrows of the mammals. Unsurprisingly, it seems there is a community of rove beetles utilizing mammals in Tasmania (and almost certainly Australia and the Neotropics) at varying degrees, from the predatory, potentially mutualistic *Myotyphlus* to the coprophagous/detritivorious *Anotylus* and *Oxytelus*. This community, in combination with the ectoparasites (e.g. ticks and fleas) that also occur on and around the mammals should be the focus of future research. Perhaps individuals of *Anotylus* and *Oxytelus* are preyed upon by *Myotyphlus* when/if they co-occur in the mammal burrows.

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References

BUBELA, T.M. and HAPPOLD, D.C.D. 1993. The social organisation and mating system of an Australian subalpine rodent, the broad-toothed rat, *Mastacomys fuscus* Thomas. *Wildlife Research* **20**: 405–417.

BUBELA, T.M., HAPPOLD, D.C.D and BROOME, L.S. 1991. Home range and activity of the broad-toothed rat, *Mastacomys fuscus*, in subalpine heathland. *Wildlife Research* **18**: 39–48.

CARRON, P.L., HAPPOLD, D.C.D. and BUBELA, T.M. 1990. Diet of two sympatric Australian subalpine rodents, *Mastacomys fuscus* and *Rattus fuscipes*. *Australian Wildlife Research* **17**: 479–489.

ERICHSON, W.F. 1840. *Genera et species Staphylinorum Insectorum Coleopterorum Familiae*. Pp. i–viii, 1–954, pls. 1–5. F.H. Morin: Berolini.

FAUVEL, A. 1878. Les staphylinides de l'Australie et de la Polynésie. *Annali del Museo Civico di Storia Naturale di Genova* **13**: 465–598.

FAUVEL, A. 1883. *Amblyopinus* et *Myotyphlus*. *Revue d'Entomologie* **2**: 37–40.

GRAY, J.E. 1841. Contributions towards the geographical distribution of the Mammalia of Australia, with notes on some recently discovered species, in a letter addressed to the Author. Appendix C. Pp. 397–414 *in* Grey, G.R., *Journals of Two Expeditions of Discovery in North-west and Western Australia, During the Years 1837, 38, and 39, Under the Authority of Her Majesty's Government.* Describing Many Newly Discovered, Important, and Fertile Districts, with Observations on the Moral and Physical Condition of the Aboriginal Inhabitants, &c., &c. T. & W. Boone: London.

JENKINS SHAW, J., KWAK, M.L., BURNS, P.A. and SOLODOVNIKOV, A. 2017. New host records of the rove beetle *Myotyphlus newtoni* Solodovnikov & Jenkins Shaw, 2016 (Coleoptera: Staphylinidae: Staphylininae), with notes of its association with mammals. *Australian Entomologist* **44**: 209–212.

JENKINS SHAW, J., ŻYŁA, D. and SOLODOVNIKOV, A. 2020. Molecular phylogeny illuminates Amblyopinini (Coleoptera: Staphylinidae) rove beetles as a target for systematic and evolutionary research. *Systematic Entomology* **45**: 430–446.

MAKRANCZY, G. 2006. Systematics and phylogenetic relationships of the genera in the *Carpelimus* group (Coleoptera: Staphylinidae: Oxytelinae). *Annales Historico-Naturales Musei Nationalis Hungarici* **98**: 29–120.

MATTHEWS, A. 1878. On the genus *Amblyopinus* and description of a new species from Tasmania. *Cistula Entomologica* **2**: 275–279.

SMISSEN, P.J. and ROWE, K.C. 2018. Repeated biome transitions in the evolution of Australian rodents. *Molecular Phylogenetics and Evolution* **128**: 182–191.

SOLODOVNIKOV, A. and JENKINS SHAW, J. 2017. The remarkable Australian rove beetle genus *Myotyphlus*: its cryptic diversity and significance for exploring mutualism among insects and mammals (Coleoptera: Staphylinidae). *Austral Entomology* **56**: 311–321.

THOMAS, O. 1882. On two new Muridae from Tasmania. *Annals and Magazine of Natural History* (5) **9**: 413–416.

TROUESSART, E.-L. 1897. Catalogue Mammalium tam Viventium quam Fossilium. Nova edition (Prima complete). Tom. 1. Fasc. III, Rodentia II. (Myomorpha, Hystrichomorpha, Lagomorpha.). Berolini: R. Friedländer & Sohn.

WOINARSKI, J. and BURBIDGE, A.A. 2016. *Mastacomys fuscus*. *The IUCN Red List of Threatened Species* 2016: e.T18563A22429430. https://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T18563A22429430.en. Downloaded on 17 June 2020.

NEW BUTTERFLY (LEPIDOPTERA) RECORDS, LIFE HISTORIES AND HOST PLANTS FOR CHRISTMAS ISLAND, AUSTRALIA

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Abstract

The butterflies, *Melanitis phedima phedima* (Cramer, [1780]) (Nymphalidae) and *Junonia orythia minagara* (Fruhstorfer, 1904) (Nymphalidae) are recorded from Christmas Island, Indian Ocean, Australia for the first time, with *M. p. phedima* representing a new record for Australia. The historic taxonomic treatment of specimens of *M. p. phedima* from the island is also discussed. Life histories of *Eurema alitha amplexa* (Butler, 1887) (Pieridae) and *Charaxes andrewsi* Butler, 1900 (Nymphalidae) are described for the first time. Several new larval host plants are recorded for these two species, and for *Eurema blanda blanda* (Boisduval, 1836) (Pieridae), *Nacaduba kurava nemana* Fruhstorfer, 1916 and *Jamides bochus* Stoll, 1782 (both Lycaenidae). Observations for *Catopsilia pomona* (Fabricius, 1775) (Pieridae), *Hypolimnas misippus* (Linnaeus, 1764) (Nymphalidae) and *Petrelaea tombugensis* (Röber, 1886) (Lycaenidae) are compared with observations made during previous surveys. A total of 30 species of butterfly are now confirmed from Christmas Island.

Keywords: *Melanitis phedima phedima*, *Junonia orythia minagara,* biological observations

Introduction

The Australian Territory of Christmas Island, an area of 135 km^2, located in the Indian Ocean, is 380 km south of Java and 2650 km north-west of Perth, Western Australia. Moulds and Lachlan (1987) provided a detailed collection history and checklist of the butterfly fauna of the island with 22 species recorded. *Euploea climena macleari* (Butler, 1887), *Charaxes andrewsi* Butler, 1900, and *Eurema alitha amplexa* (Butler, 1887) are endemic to Christmas Island (Moulds and Lachlan 1987, James *et al.* 2019). Since Moulds and Lachlan (1987),, Wilson and Johnson (2017), and Johnson and Wilson (2018) added a further seven species from the island with the life history of *E. climena macleari* recently being described (Wilson and Johnson 2017).The life histories of the latter two endemics have previously been unknown.

The authors visited Christmas Island from 3–14 March 2020, and while undertaking general biological observations, discovered the life histories of *E. alitha amplexa* and *C. andrewsi*. This paper reports on observations of several butterfly taxa on the island and describes the life histories of *E. alitha amplexa* and *C. andrewsi*. All collecting was conducted under permits for National Parks and Crown Reserves with specimens lodged in the Museum of Tropical Queensland, Townsville (MTQ).

Observational records and discussion

Family Pieridae

Catopsilia pomona (Fabricus, 1775)

Johnson and Wilson (2018) reported that in 2017, *C. pomona* was rarely observed, with only several confirmed sightings over this 11-day survey. In contrast, during the 2020 survey, *C. pomona* was very common in urban areas, particularly where

Cassia fistula L. (Caesalpiniaceae) was growing. Eggs, larvae and pupae were commonly observed on this host plant.

Eurema blanda blanda (Boisduval, 1836)

Recorded host plants of *E. b. blanda* on Christmas Island are *Caesalpinia bonduc* (L.) Roxb. (Fabaceae) and *Pithecellobiun dulce* (Roxb.) Benth. (Fabaceae) (Wilson and Johnson 2017) but in 2020, immature stages of *E. b. blanda* were oddly not observed on either of these plants. In addition, Wilson and Johnson (2017) reported that immature stages were not observed on *C. fistula*, a recorded host plant by Parsons (1998) in Papua New Guinea. While observing *C. pomona* on *C. fistula* in 2020, egg batches (Fig. 1), first instar larvae (Fig. 2) and semi-mature larvae (Fig. 3) of *E. b. blanda* were observed on the immature leaves of *C. fistula*. Several egg batches and first instar larvae were also observed on *Delonix regia* (Bojer ex Hook.) Raf. (Fabaceae) (Fig. 4). However, the larvae on *D. regia* fed sparingly and died after five days.

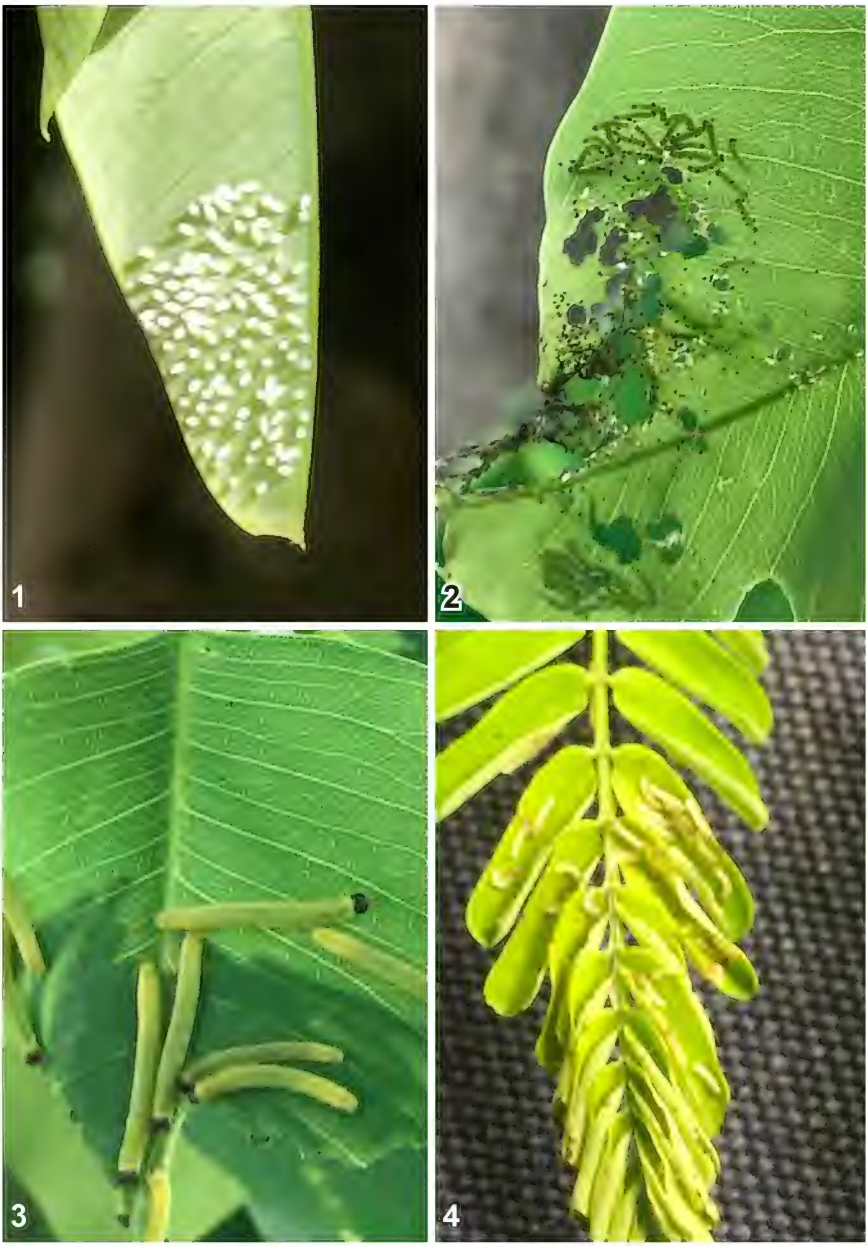
Family Nymphalidae

Melanitis phedima phedima (Cramer, [1780b])

Melanitis phedima phedima constitutes a new species record for Christmas Island and Australia. *Melanitis phedima* ranges from India, Sri Lanka, Myanmar, China and Japan through the Malay Peninsula and the Philippines to Indonesia (D'Abrera 1985, Savela 2020).

D.J. Phillips collected four males in 1989 (Parks Australia specimens labelled: 'D.J. Phillips 1989 (4/2), settlement'). A single female specimen also exists in the Australian National Insect Collection (ANIC) labelled 'Christmas Island, Ethel Beach, 18 April 1989, J.C. Cardale, at light' (Michael Braby, pers. comm.), but was initially identified as *M. leda* (Linnaeus, 1758). Caitlyn Pink sighted several specimens at Flying Fish Cove in April–May 2019, and collected a single male specimen (Figs 5, 6), which was donated for lodgement in the MTQ.

The adult morphology of the six most recent specimens (5♂♂, 1♀) matches *M. p. phedima* from Java, Indonesia (D'Abrera 1985), 380 km north of Christmas Island. Compared to *M. leda bankia* (Fabricius, 1775) from Australia, the Christmas Island males (Figs 5, 6) have a much darker brown upperside wing surface which is slightly paler towards the wing base and towards the apex of the wings. The forewing upperside has an elongated triangular black subapical patch between veins M_2 and M_3 with a white spot towards the outer edge of the patch, a second lower rounded black patch between veins M_3 and CuA_1 bearing a central faint white spot, darker black scaling towards the costa from the two subapical patches, with a slight "tooth" produced on the termen at vein M_2. The black patches are not inwardly edged with orange as in *M. l. bankia*. The hindwing upperside has one small subterminal black spot with a central obscure white spot. The apex and termen of both wings are more rounded than in *M. l. bankia*. The underside is a mottled variegated grey brown with black shading, with smaller ocelli. The forewing underside has a larger ocellus between veins M_3 and CuA_1 with a central



Figs 1–4. Eggs and larvae of *Eurema blanda blanda* on *Cassia fistula* and *Delonix regia* from Christmas Island: (1) eggs on *Cassia fistula*; (2) first instar larvae on *Cassia fistula*; (3) semi-mature larvae on *Cassia fistula*; (4) first instar larvae on *Delonix regia*.

very obscure pale spot, two very restricted obscure subapical ocelli and another obscure ocellus at M_2 to M_3 opposite the larger white spot on the upperside. The hindwing underside has six subterminal ocelli of which the one between veins Rs and M_1 is the larger with a faint pale white spot, and the remainder obscure.

The female in the ANIC (Figs 7, 8) has similar markings to the male, but is a lighter orange brown, with the "tooth" more produced on the forewing termen at vein M_2, a distinct dark patch towards the costa from the two black subapical patches between veins M_2 and M_3 and M_3 and CuA_1 as in the male and an obvious paler brown band surrounding the black subapical patches and towards the apex. Two obscure back spots with a central very obscure pale spot occur on the hindwing upperside. The hindwing underside has similar markings to the male but is lighter orange brown, with ocelli more distinct and no ocellus between veins M_1 to M_2. The female of *M. p. phedima* is like the female *M. l. bankia* but is distinguished by the darker colouration and marked reduction of the two subapical black patches on the forewing.

Comparison with the four specimens collected by D.J. Phillips shows little variation other than the forewing termen not having a produced "tooth" at vein M_2, while one specimen has a very reduced subterminal forewing black spots with no white spots on the upperside, and all specimens show variability in the prominence of the underside ocelli. Wingspan varies from 56–62 mm. These specimens have a brown upper surface indicating the wings have faded since the original collection in 1989. As with other *Melanitis* species, seasonal variations are likely.

Butler (1900) originally described the species as *M. ismene* var. *determinate* and indicated that the single historical female specimen collected during a 10-month expedition in 1897–1898 "does not show the characteristics of *M. leda*". Subsequently, this species was mistaken for *M. leda* which is superficially similar. *Melanitis phedima* is rare on the island, with only seven specimens located by us. The identity of the original female specimen, which is presumed to be in the British Museum, was not available at the time of this report due to COVID-19 restrictions in accessing the Museum.

Hypolimnas misippus (Linnaeus, 1764)

During our previous visit to the island in 2017 (Johnson and Wilson 2018) *H. misippus* was not sighted, but in 2020, one male was collected in the urban area at Rocky Point on the northern side of the island. At this locality, a recorded host plant *Asystasia gangetica* (L.) T. Anderson (Acanthaceae) (Braby 2000) was a common ornamental weed. Another reported host plant, *Portulaca* sp. L. (Portulacaceae), occurs on exposed areas adjacent to the sea cliffs at Steep Point on the north-eastern side of the island and at Western Beach at the far western side of the island (Alasdair Grigg pers. comm.). After our departure from the island in 2020, Caitlyn Pink (pers. comm.) observed several females of this species in the urban area and in other parts of the island.

Figs 5–8. *Melanitis phedima phedima* from Christmas Island: (5) male, upperside (wingspan 62 mm); (6) male, underside; (7) female, underside (Photo: M.F. Braby); (8) female, underside (Photo: M.F. Braby).

Junonia orythia minagara (Fruhstorfer, 1904)

Junonia orithya minagara (Figs 9–12) is a new record for Christmas Island and Australia. *Junonia orithya* (Linnaeus, 1758) occurs widely from Africa and China, through South-east Asia, the Philippines and Indonesia, to New Guinea and adjacent islands and Australia (Braby 2000).

It was first sighted on Christmas Island by A.I. Knight in 2003 (Max Orchard, pers. comm.) but not collected, then again sighted by a birding group in 2011 (Frank Pierce, pers. comm.) and again by Caitlyn Pink in 2019 (pers. comm.). During our 2020 survey, we frequently observed *J. orithya* at several locations, such as the urban area at Settlement including Rocky Point on the north of the island (uncommon), the Christmas Island Airport and adjacent areas (uncommon), the Pink House in the centre of the island (uncommon), and at South Point (common) (abundance categories correspond to Braby 2016).

Adult facies is consistent with the subspecies *J. o. minagara*, which occurs on Java, in Indonesia. When compared to *J. o. albicincta* Butler, 1875 from Australia, *J. o. minagara* is similar with differences being: (Figs 9, 10) the forewing

upperside of the male has bright orange bands in the forewing cell, blue patches on the costa and adjacent to the tornus, and the hindwing upperside is darker blue. In addition, the forewing underside basal colour is generally darker grey closer to the tornus, making the inner margin of the lower ocellus indistinct. The hindwing underside base colour is generally greyer (less cream). In the female (Figs 11, 12), the forewing upperside is black with the blue areas more obvious and more extensive adjacent to the costa. The hindwing upperside is a darker blue but variable and often more extensive, and occasionally with distinct bluish white margins, particularly towards the tornus. The forewing underside generally has the base colour grey-brown, while the hindwing underside base colour is generally greyer (less cream) but with variation in the base colour and size of the ocelli.

At Rocky Point, eggs were observed on flower buds of *A. gangetica* (Figs 13, 14) where several males and females were regularly sighted. *Asystasia gangetica* is recorded as a host plant of *J. o. albicincta* in Australia (Braby 2000), and is a common ornamental weed on the island. A larva was reared to adult on this host plant.

Adult behaviour was typical of *J. o. albicincta*, with adults frequently settling for extended periods on bare ground with wings outspread. Adults were observed in disturbed areas such as roadsides, car parks and vacant lots in the township and around the airport, and in previously mined areas that had not been rehabilitated.

Family Lycaenidae

Petrelaea tombugensis (Röber, 1886)

Petrelaea tombugensis was rarely observed by us in March 2017 (Johnson and Wilson 2018) with only two specimens collected over an 11-day period. In March 2020, adults were common around flowering trees of *Terminalia catappa* L. (Combretaceae), particularly along the strand in the town area and at Territory Day Park at Drumsite. Larvae were also common on flowers (Fig. 15) with a larva reared to pupa (Fig. 16). Larvae feed on the nectar organs of *T. catappa* flowers (Samson and Lambkin 2003).

Nacaduba kurava nemana Fruhstorfer, 1916

The host plant of *N. k. nemana* was previously unrecorded on Christmas Island. In 2017, we rarely encountered this species (Johnson and Wilson 2018) with only three specimens collected in the vicinity of the Pink House in the centre of the island. In contrast, in 2020, this species was common in the same area, including Margaret Knoll on the edge of the central plateau on the eastern side, and in the area surrounding the Christmas Island Airport. Near the Pink House, a female was observed ovipositing (Fig. 17) at the base of a terminal shoot of *Ardisia sanguinolenta* Blume. (previously *A. colorata*) (Primulaceae), a shrub to small tree to a height of six to eight metres as an understory in the rainforest (Fig. 18). This tree is distributed from India, Indochina, Myanmar and Thailand

Figs 9–14. *Junonia orithya minagara* from Christmas Island and host plant: (9) male upper side (wingspan 40 mm); (10) male underside; (11) female upperside (wingspan 41 mm); (12) female underside; (13–14) food plant *Asystasia gangetica* with eggs.

through the Malaysian Peninsula to Sumatra, Java, Borneo and Christmas Island (Ming 2014). On further examination of many plants we discovered 15 eggs and 8 hatched eggs at the base of young shoots and on petioles of young leaves. Two first instar larvae were also observed on immature leaves, but no other stages were seen. The mature leaves of the plants had extensive feeding marks, likely from previous generations. This plant species is in the same family (Primulaceae) as

many of the host plants used by the two Australian subspecies. It is highly likely that this plant is the host plant for *N. k. nemana* on Christmas Island but requires confirmation.

Jamides bochus Stoll, 1782

Wilson and Johnson (2017) reported eggs of *J. bochus* on flower buds and occasionally on the flower pedicel of *Canavalia cathartica* Thouars (Fabaceae), a scrambling vine with large bright pink pea flowers, common over the island. In March 2020, *J. bochus* adults were observed over the whole island but *C. cathartica* was not flowering and there was no evidence of immature stages anywhere on the plants. However, eggs, each with their "bubbled" gelatinous mass, were observed laid singly or more commonly in groups, on flower buds of *Macroptilium atropurpureum* (DC.) Urb., (Siratro) (Fabaceae) (Fig. 19) and *Senna barclayana* (Sweet) Randell (Fabaceae) (Fig. 20), and on the sepals of immature green seed pods of *Ipomoea nil* (L.) Roth (Convolvulaceae) (Fig. 21), all of which are common weeds of disturbed areas. Eggs were very abundant on each of these plants. Close examination of these host plants showed larval feeding inside the flower buds of *M. atropurpureum* and *S. barclayana*, while mature larvae were observed to openly consume all parts of the flowers except the sepals. A larva was reared to an adult on flowers of *M. atropurpureum*. There was no evidence of larval feeding on *I. nil*, suggesting that it is not a suitable host, despite finding eggs on the seed pods.

Life histories

Family Pieridae

Eurema alitha amplexa (Butler, 1887)

Egg (Figs 22, 23). Approximately 1.5 mm high and 0.4 mm wide; greyish-white in colour; spindle-shaped with numerous (approximately 60) indistinct vertical ridges and very faint lateral striations (chequered pattern) between the ridges, and a smooth domed top. Duration 3 days.

First instar larva (Fig. 24). Length 2 mm when first hatched growing to 3 mm; cylindrical; body white when first hatched after consuming the egg shell then becoming green after consuming the leaves of the host plant; lateral rows of tubercles cover the body, each tubercle with a miniscule drop of fluid; head greenish white. Duration 2 days.

Second instar larva (Fig. 25). Length 8 mm; cylindrical; body green; lateral rows of tubercles cover the body, each tubercule as on the first instar, more numerous and shorter than the first instar; head brownish green with numerous setae.

Semi-mature larva (Figs 26, 27). Length 16 mm; cylindrical; body green; numerous rows of tubercles cover the body each as in the first two instars, proportionally shorter than previous instars; a greenish yellow lateral stripe; head green with numerous short setae.

Figs 15, 16. Larva and pupa of *Petrelaea tombugensis* from Christmas Island on *Terminalia catappa*: (15) mature larva on *T. catappa* flowers; (16) pupa.

Figs 17, 18. Egg and host plant *Ardisia colorata* of *Nacaduba kurava nemana* from Christmas Island: (17) egg; (18) host plant *Ardisia colorata*.

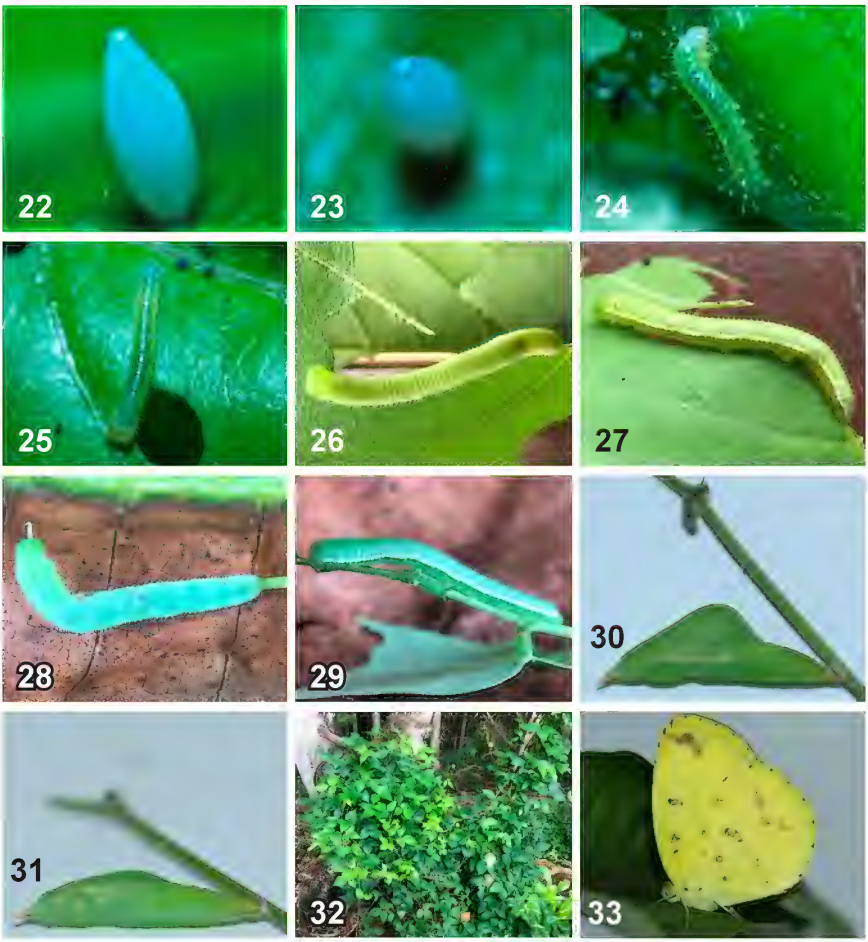
Figs 19–21. Plants with *Jamides bochus* eggs: (19) on Siratro (*Macroptilium atropurpureum*) flowers; (20) on *Senna barclayana* flowers; (21) on *Ipomoea nil* sepals.

Final instar larva (Figs 28, 29). Length 21–29 mm (average 24 mm, n=5); cylindrical; body bluish green; numerous rows of short tubercles; a white lateral line; head green with numerous short setae.

Pupa (Figs 30, 31). Length 16–17 mm; green; attached by cremaster and a girdle; distinctly "keeled" ventrally; a pointed head projection, paler that the body; a faint brown mid-dorsal line extending onto the head projection; a pale whitish green band edged with faint brown along the dorsal part of the wing pad. Duration 5 days.

Biology

Butterflies were observed ovipositing singly on the upperside of semi-immature to semi-mature leaves of *Strongylodon lucidus* (G. Forst.) Seem. (Fabaceae) (Fig. 32), an uncommon scrambling vine on the island that occurs adjacent to roads and tracks through the forest. The plant occurs widely from Madagascar, Sri Lanka, Indonesia, Christmas Island, the Philippines, New Guinea, north-eastern Australia to the Pacific Islands, including the Solomon Islands, Samoa, Tonga and Hawaii (Du Puy and Telford 1993). Eggs collected immediately after being laid by three separate females hatched in three days. Larvae initially consumed



Figs 22–33. Immature stages and host plant of *Eurema alitha amplexa* on Christmas Island: (22) egg (lateral view); (23) egg (dorsal view); (24) first instar larva; (25) second instar larva; (26) semi-mature larva (dorsal view); (27) semi-mature larva (lateral view); (28) final instar larva (dorsal view); (29) final instar larva (lateral view); (30) pupa (lateral view); (31) pupa (dorsal view); (32) host plant *Strongylodon lucidus*; (33) newly emerged *E. a. amplexa* (Christmas Island 2020: Photo: Caitlyn Pink).

the semi-immature to semi-mature leaves, but not the very immature or mature leaves. Late instar larvae mainly consumed the semi-mature to mature leaves, resting on leaves or stems. Larval period was not recorded.

Larvae pupated on stems of the host plant with the pupal colour and shape closely matching the leaves and stems. Egg-laying was firstly observed just east of the cemetery on Gaze Road on the northern side of the island in the general locality

where Johnson and Wilson (2018) previously reported the species to be common to very common (abundance categories according to Braby 2016). The butterfly (Fig. 33) was generally uncommon over the rest of the island in 2020. Many eggs and several larvae were observed on many of the host plants, but larvae were heavily infected with a disease where larvae turned black, became limp and oozed black liquid and consequently resulted in the death of many reared larvae.

The life history of *E. a. amplexa* from Christmas Island closely matches that of *Eurema alitha esakii* Shirôzu, 1953 from Taiwan reported by Igarashi and Fukuda (2000) and Lyu and Chen (2015), and the life history of *E. a. novaguineensis* (Shirôzu & Yata, 1982) in Australia (Braby 2000, Jenkinson 2008) in Australia, and Parsons (1998) in Papua New Guinea. Examination of photos of the immature stages of *E. a. novaguineensis* from Mt Burrell and Coolabah Station in the Northern Territory (supplied by M.F. Braby) show similarities. When compared to *E. alitha* from Taiwan, the *E. a. amplexa* egg is less pointed but the larvae appear the same. The pupa of *E. a. amplexa* though has a faint brown dorsal line and a pale whitish green band edged with faint brown along the dorsal part of the wing pad, which is in contrast to the pupa of the Taiwan subspecies, which has a prominent white dorsal line; a white band along the dorsal part of the wing pad; and numerous dark brown to black spots over the body of the pupa. When compared to *E. a. novaguineensis* from Australia, the egg and larva of *E. a. amplexa* is identical but the pupa of *E. a. novaguineensis* differs in that it has a faint pale brown dorsal line that does not extend onto the head projection; a white (not pale whitish green with a faint brown edge) band along the dorsal part of the wing pad; and a more pointed cremaster.

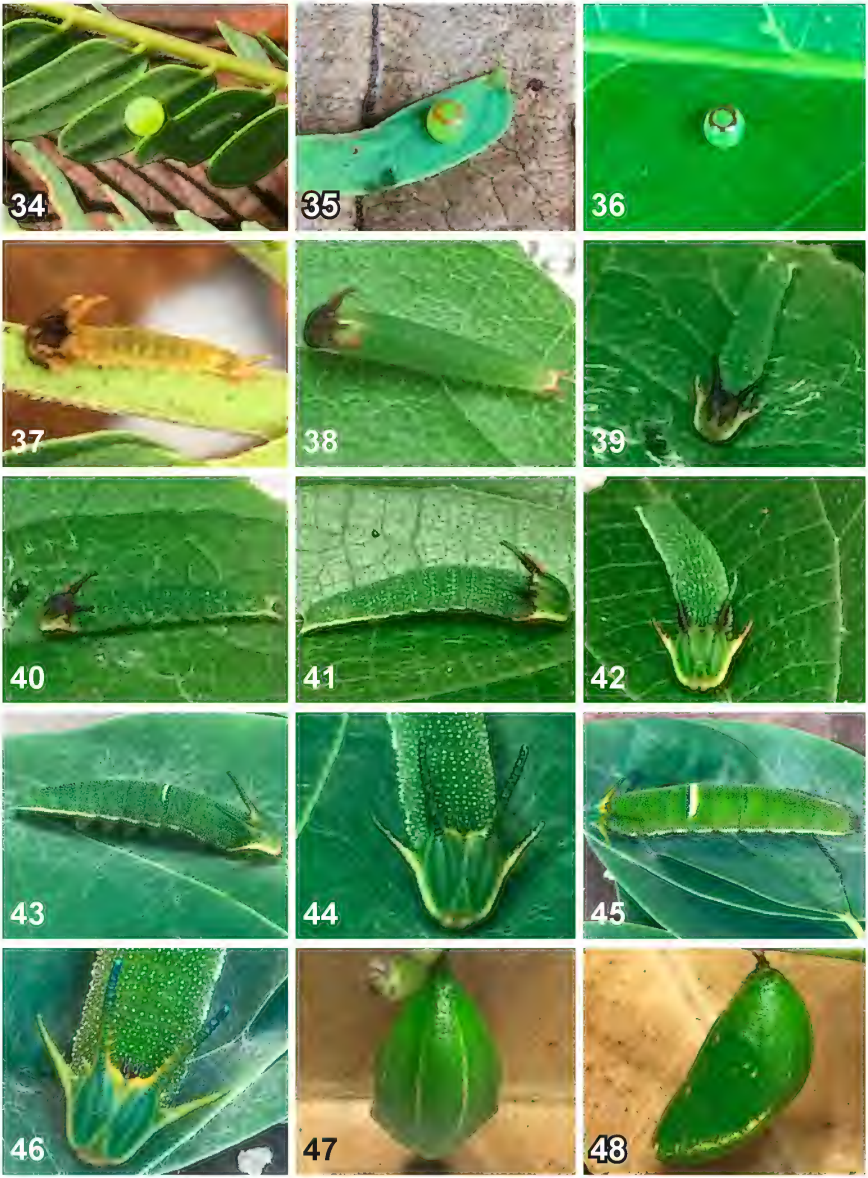
James *et al*. (2019), in their review of endemic species of Christmas Island, reported that *Terias amplexa* (*E. amplexa*) was a synonym of *Eurema hecabe* (Corbet and Pendlebury 1932, Pendlebury 1933, Gibson-Hill 1947), but Moulds and Lachlan (1987) later recognised it as a distinct species. Yata (1995) then, considered it to be a subspecies of *E. alitha*, based on the male genitalia and the shape and size of the sex scales on vein CuA on the underside of the male forewing.

Family Nymphalidae

Charaxes andrewsi Butler, 1900

Egg (Figs 34–36). Globular, 1.8 mm in diameter and 1.5 mm high when first laid, reducing to 1.4 mm high on day 3; uniformly green when first laid (Fig. 34), developing a reddish-brown ring on day two (Fig. 35), top of egg reducing on day three to a "saucer shape" with a distinct dark brown rim containing numerous obscure ribs (Fig. 36). Duration 6 days.

First instar larva (Figs 37, 38). Larva 5 mm on hatching, growing to 7 mm; cylindrical; body pale yellowish-brown when first hatched (Fig. 37) with a few short pale setae, body becoming green when consuming the host plant (Fig. 38), developing faint cream spots over the body in the later stage; head pale brown



Figs 34–48. Immature stages of *Charaxes andrewsi* on Christmas Island: (34) newly laid egg; (35) egg after one day; (36) egg after two days; (37) newly hatched first instar larva; (38) first instar larva after 5 days; (39–40) second instar larva; (41–42) third instar larva; (43–44) fourth instar larva; (45–46) final instar larva; (47) pupa dorsal view; (48) pupa lateral view.

with dark brown central patches below the two larger inner horns, and brown outer margins of the head, two pairs of horns with inner horns larger, pale brown initially then becoming dark brown, head and horns rugose; anal segment flattened with two pale brown horns. Duration six days.

Second instar larva (Figs 39, 40). Length 12 mm; cylindrical; body green with many very short pale setae and numerous distinct cream spots, interrupted pale green lateral band becoming continuous on the last three abdominal segments; head rugose brownish-green with distinct central dark brown areas on top of head, outer edge cream extending to the outer horns, central horns dark brown and distinctly longer than earlier instar, horns distinctly rugose; anal segment with two cream horns shorter than the previous instar.

Third instar larva (Figs 41, 42). Length 17 mm; cylindrical; body green with numerous pale bluish white spots, distinct interrupted cream lateral band becoming continuous on the posterior half; head green with slightly darker green bands from the inner horns to the lower head, outer edge of head cream extending to the outer horns, inner horns dark brown on the lower part becoming green then bluish green towards the tip, blue at very tip and longer than previous instar, two minute central black projections, all horns rugose; anal segment with two short horns edged cream.

Fourth instar larva (Figs 43, 44). Length 30 mm; body similar to previous instar with numerous distinct bluish white spots, distinct mid-dorsal multi-coloured band on the third abdominal segment with narrow black anterior band, white central band, yellow curved posterior band; horns very rugose with very short side projections, inner horns green becoming bluish green towards tip, blue at very tip, two black central projections; anal segment green with outer margins cream.

Final instar larva (Figs 45, 46). Body 53 mm; body similar to previous instar except slightly paler green, mid-dorsal band very distinct with obscure black mid-dorsal band on abdominal segment five; head green with darker green bands as for previous instar, edged pale green on outer margins, bright yellow between the two inner horns, outer horns yellowish green, inner horns green on the lower part becoming distinctly bluish green then blue at the tips, two black central projections, all horns distinctly rugose with short side projections on the lower part of the horns particularly on the outer horn extending to the lower "cheek" area under the head; anal segment dark green edged with cream on the outer margin.

Pupa (Figs 47, 48). Length 27 mm, width 12 mm; stout, smooth; colour green, two curved sub-dorsal pale cream stripes on abdomen becoming parallel on thorax extending towards the head, each segment with two pale cream spots between and either side of the sub-dorsal stripes on the abdominal segments extending to the thorax, a few other pale cream spots scattered over the lower abdomen and thorax; slight ridge along forewing distinctly cream, scattered pale cream spots

Figs 49, **50.** Common weeds on Christmas Island subject to oviposition by *Charaxes andrewsi*: (49) *Leucaena leucocephala* on a roadside; (50) *Delonix regia* on roadside.

over wings with spots arranged in short rows on three of the veins towards the margins; head with a prominent larger cream spot over eye, a few scattered pale cream spots; cremaster green with four small rounded protuberances towards the pupa body.

Biology

Although the pre-pupal larva and pupa of *C. andrewsi* were photographed by Parks Australia (2016) on *Celtis timorensis* Span. (Cannabaceae), the early stages were not described. During the 2020 survey, *C. andrewsi* was uncommon with one to four adults sighted each day during the survey. Five females were observed laying eggs at the airport, South Point, Settlement Day Park at Drumsite, Gaze Road near the cemetery on the north of the island, and on Golf Course-Casino Road on the north-east of the island. Thus females were observed ovipositing: seven eggs on *Leucaena leucocephala* (Lam.) de Wit (Fabaceae), four on Poinciana *Delonix regia*, and three on *Tristiropsis a* Radlk. (Sapindaceae) which is a common native rainforest tree. In addition, another egg was found on *L. leucocephala* growing along a roadside. Of the 15 eggs, 70% were laid on the upper surface of the leaf and the remainder under the leaf, and all laid from 1.5 to 4 m from ground level. Females took only 3-4 seconds to lay their eggs before flying to another plant, or another branch of larger trees. All eggs were laid on the more 'open' side of the plant, such as along roads or in parks. *Leucaena leucocephala* (Fig. 49) and *D. regia* (Fig. 50) are major weeds on the island, particularly along roads, tracks and other disturbed areas.

Eggs hatched on the sixth day and all larvae consumed their egg shells, then commenced feeding on the edge of the *D. regia* and *T. acutangula* leaf on which the egg was laid. A first instar larva from *L. leucocephala* placed on *C. timorensis*, a recorded host plant (Parks Australia 2016), also consumed the edge of the leaf. The newly hatched larva on *L. leucocephala* did not eat any leaf and died after two days. On the fourth day after hatching, larvae rested on the central mid-rib of the leaf, constructing a silk pad, and consumed the leaf margins. The body colour

closely matched the host plant and only the head was clearly visible. The first instar larvae on *D. regia*, *T. acutangula* and *C. timorensis* died after six to seven days.

Observations on the other early stages on *C. timorensis* and the first instar from hatched eggs (above) showed that during the first four instars, the larva consumed leaves throughout the day and night resting intermittently on the silk pad, resulting in rapid development. The final instar consumed the leaves almost exclusively at night. Pupation was on a branch near the silk pad.

Delonix regia is a reported host plant for *Charaxes sempronius* (Fabricius, 1793) in Australia (Braby 2000). No larvae survived on *L. leucocephala*, perhaps suggesting that the minosine toxin in *L. leucocephala*, known for its insecticidal activity (Ahmed *et al*. 2014), may have contributed to the mortality of *C. andrewsi*.

The observed females showed an apparent preference for laying eggs on legumes (*L. leucocephala* and *D. regia*). Although the first instar larva on *D. regia*, *T. acutangula* and *C. timorensis* readily ate the leaves of these plants, they died after six to seven days, thought to be from disease, which was consistent with other numerous disease related deaths of our livestock on the island. Thus, the suitability of *D. regia* and *T. acutangula* as host plants requires confirmation.

Summary

Thirty species are now recorded from Christmas Island. However, the identity and occurrence of *Prosotas aluta* (Druce, 1873) remains in doubt and this is supported by the original report of Pendlebury (1993) who stated that "the original specimen was too worn for positive identification".

Christmas Island suffered an extreme period of drought in 2019 until heavy rains in the months prior to our arrival which resulted in the vegetation on the island being in excellent condition during our survey. It was noted that some species were much more common than we experienced in 2017 (*N. k. nemana, Prosotas dubiosa* (Semper, 1879), *C. pomona* and *J. bochus*) and some far less common than in 2017 (*Appias olferna* Swinhoe, 1890, *E. b. blanda, E. a. amplexa, Borbo cinnara* (Wallace, 1866), *Badamia exclamations* (Fabricius, 1775) and *Hasora chromus* (Cramer, 1780a)). Adults of *Hypolimnas anomala* were not as common, but in 2020 larvae of all stages were observed in high numbers.

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A special thanks to A/Prof M.F. Braby who supplied overseas reference material on *Eurema alitha* and photos of the immature stages from the Northern Territory and the identification of *M. p. phedima* and photos of the female specimen in the ANIC (Photographs copyright M.F. Braby).

References

AHMED, A.M.M., AYILES, L.R., SAMCHEZ, F.J.S., Al-ZYOUD, F.A. and RODRIGUEZ, M.B. 2014. An overview on some biotic and abiotic factors affecting the population dynamics of *Leucaena* Psyllid, *Heteropsylla cubana* Crawford (Homoptera: Psyllidae): Contributory factors for pest management. *Tropical and Subtropical Agroecosystems* **17:** 437–446.

BOISDUVAL, J.B.A. 1836. *Histoire naturelle des insectes. Species général des Lépidoptères*. Roret: Paris; vol. 1, pp. xii + 690 + 6, pls. 1–24.

BRABY, M.F. 2000. *Butterflies of Australia: their identification, biology and distribution.* CSIRO Publishing, Melbourne; xx + 976 pp.

BRABY, M.F. 2016. *The complete field guide to butterflies of Australia*. 2nd edn. CSIRO Publishing, Melbourne; xi + 384 pp.

BUTLER, A.G. 1875. Contributions towards a knowledge of the Rhopalocera of Australia. *Transactions of the Entomological Society of London* **1875:** 1–10.

BUTLER, A.G. 1887. Lepidoptera. Pp. 522–523 *in* Günther, A., Report on a zoological collection made by the officers of H.M.S. 'Flying-Fish' at Christmas Island, Indian Ocean. *Proceedings of the Zoological Society of London* **1887:** 507–526, pls. 41–44.

BUTLER, A.G. 1900. Lepidoptera Rhopalocera. In Andrews, C.W. (ed). *A Monograph of Christmas Island (Indian Ocean): Physical Features and Geology with descriptions of the Fauna and Flora*. British Museum Trustees: London; pp 60–63.

CORBET, S. and PENDLEBURY, H.M. (1932). A revision of the Indo-Australian forms of the genus *Eurema* with special reference to the Malaysian forms. *Bulletin of the Raffles Museum* **7:** 143–193.

CRAMER, P. [1780a]. *De Uitlandsche Kapellen voorkomende in de drie waereld-deelen Asia, Africa en America*. Wild: Amsterdam, Baalde and Utrecht; Vol. 3, pp. 105–176, pls. 253–288.

CRAMER, P. [1780b]. *De Uitlandsche Kapellen voorkomende in de drie waereld-deelen Asia, Africa en America*. Wild: Amsterdam, Baalde and Utrecht; Vol. 4, pp. 1–252, pls. 289–400.

D'ABRERA, B. 1985. *Butterflies of the Oriental Region. Part II. Nymphalidae, Satyridae, Amathusidae*. Hill House, Melbourne; pp 410–413.

DU PUY, D.J. and TELFORD, I.R.S. 1993. *Fabaceae, Flora of Australia*. Vol **50:** 204–236. Australian Government Publishing Services, Canberra.

FABRICIUS, J.C. 1775. *Systema Entomologiae, sistens Insectorvm Classes, Ordines, Genera, Species, adiectis Synonymis, Locis, Descriptionibvs, Observationibvs*. Officina Libraria Kortii: Flensburgi et Lipsiae; pp. [i–xxxii,] 1–832. .

FRUHSTORFER, H. 1904. Neue *Iunonia*-Rassen. *Insekten-Börse* **21:** 325.

FRUHSTORFER, H. 1916. Revision der Gattung *Nacaduba* auf Grund der Morphologie der Generationsorgane. *Zoölogische mededeelingen uitgegeven door het Rijksmuseum van natuurlijke historie te Leiden* **2:** 103–140, pls. 4 and 5.

GIBSON-HILL, C.A. 1947. Lepidoptera (Rhopalocera). *Bulletin of the Raffles Museum* **18:** 74–80.

IGARASHI, S. and FUKUDA, H. 2000. *Life histories of Asian butterflies*. Vol 2. Tokai University Press; 711 pp.

JAMES, D.J., GREEN, P.T., HUMPHREYS, W.F. and WOINARSKI, J.C.Z. 2019. Endemic species of Christmas Island, Indian Ocean. *Records of the Western Australian Museum* **34:** 55–114.

JENKINSON, W. 2008. Life history notes on the Scalloped Grass-yellow, *Eurema alitha* (C. & R. Felder 1862) Lepidoptera: Pieridae. *Magazine of the Butterfly and Other Invertebrates Club* **51:** 10–13.

JOHNSON, I.R. and WILSON, P.R. 2018. A survey of butterflies (Lepidoptera) of Christmas Island (Indian Ocean) in March 2017. *Australian Entomologist* **45:** 159–180.

LINNAEUS, J. 1758. *Systema Naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis*. Laurentii Salvii: Holmiae; vol. 1. 10th edition. Pp. [ii] + 824.

LINNAEUS, J. 1764. *Museum Ludovicae Ulricae Reginae Svecorum, Cothorum, Vindalorumque*. Salvias: Holmiae; pp. [viii] + 720 + [2].

LYU, Z.J. and CHEN, J.R. 2015. *The life history of butterflies in Taiwan*. Morning Star Publishing Inc., Taiwan.

MING, H.C. 1999. New synonyms and combinations in Asiatic *Ardisia* (Myrsinaceae). *Blumea* **44:** 391–406.

MOULDS, M.S. and LACHLAN, R.B. 1987. The butterflies (Lepidoptera) of Christmas Island, Indian Ocean. *Australian Entomological Magazine* **14:** 57–66.

PARSONS, M. 1998. *The butterflies of Papua New Guinea: their systematics and biology*. Academic Press, London; xvi + 900 pp.

PARKS AUSTRALIA. 2016. *Annual report for the Christmas Island minesite to forest rehabilitation (CIMFR) Program, July 2015–June 2016*. p 16. https://www.righttoknow.org.au/request/3270/response/9197/attach/2/FOI%20170312%20Attachment%20C%20documents%20for%20release.pdf

PENDLEBURY, H.M. 1933. On a small collection of butterflies from Christmas Island, Indian Ocean. *Bulletin of the Raffles Museum* **8:** 94–97.

RÖBER, J.K.M. 1886. Neue Tagschmetterlinge der indo-australischen Fauna. *Deutsche entomologische Zeitschrift Iris* **1:** 45–72, pls. 2–5.

SAMSON, P.R. and LAMBKIN, T.A. 2003. The immature stages and seasonality of *Petrelaea tombugensis* (Rober) (Lepidoptera: Lycaenidae). *Australian Entomologist* **30:** 181–183.

SAVELA, M. (2020) Lepidoptera Index. Website accessed 1 June 2020. https://www.nic.funet.fi/pub/sci/bio/life/insecta/lepidoptera/ditrysia/papilionoidea/nymphalidae/satyrinae/melanitis/

SEMPER, G. 1879. Beitrag zur Rhopalocerenfauna von Australien. *Journal des Museum Godeffroy* **14:** 138–194, pls. 8 and 9.

SHIRÔZU, T. 1953. New or little known butterflies from the north-eastern Asia, with some synonymic notes. II. *Sieboldia* **1:** 149–159, pl. 19.

SHIRÔZU, T. and YATA, O. 1982. New names for six subspecies belonging to four *Eurema* species (Lepidoptera, Pieridae). *Tyô to Ga* **33:** 25.

STOLL, C. 1782. *In* Cramer, P., *De Uitlandsche Kapellen voorkomende in de drie waereld-deelen Asia, Africa en America*. Wild: Amsterdam, Baalde and Utrecht; Vol. 4, pp. 165–252, pls. 373–400.

WALLACE, A.R. 1866. *In* Wallace, A.R. and Moore, F., List of lepidopterous insects collected at Takow, Formosa, by Mr. Robert Swinhoe. *Proceedings of the Zoological Society of London* **1866:** 355–365.

WILSON, P.R. and JOHNSON, I.R. 2017. Five new butterfly life histories (Lepidoptera) from Christmas Island, Australia. *Australian Entomologist* **44:** 181–195.

YATA, O. 1995. A revision of the Old World species of the genus *Eurema* Hubner (Lepidoptera, Pieridae). Part V. Description of the *hecabe* group (part). *Bulletin of the Kitakyushu Museum of Natural History* **14:** 1–54, pls 1–35.

A NEW DISTINCTIVE CADDISFLY SPECIES OF THE GENUS *PLECTROCNEMIA* STEPHENS FROM NORTH-EASTERN AUSTRALIA (TRICHOPTERA: POLYCENTROPODIDAE)

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Abstract

At present the genus *Plectrocnemia* Stephens, 1836 is known in Australia from seven described species, among which two groups can be recognised based on the form of their male genitalia. Several other undescribed species that conform with either of these two groups are recognised in museum collections. However, examination of relatively recently collected material from north-eastern Queensland has yielded two male specimens of a species with very distinctive genitalia and these are described here as *P. robotica* **sp. n.** The status of the genus *Tasmanoplegas* Neboiss, 1977, variously synonymised with *Plectrocnemia* or recognised as a valid genus, is discussed briefly.

Keywords: Queensland, Wet Tropics, new species

Introduction

Stephens (1836) erected the genus *Plectrocnemia* Stephens, which has approximately 175 species worldwide (Morse, 2020). The genus is found in most regions of the world, is most common in the Oriental (with about 70 species) and the Western Palaearctic (with about 57 species) regions, and not reported from the Neotropical and Afrotropical regions (Morse, 2020). Six species are recorded from Australia, the first species described was *P. australica* (Banks, 1939), followed by four Tasmanian species, *P. altera* Neboiss, *P. caudata* Neboiss, *P. lacuna* Neboiss and *P. manicata* Neboiss, *P. spilota* (Neboiss) (all Neboiss, 1977) and *P. eximia* Neboiss from south Western Australia (Neboiss, 1982). In Australia, *Plectrocnemia* larvae generally occur in upland streams with predominantly cobble substrate in eastern and southern Australia (Suter *et al*. 2006).

The monotypic Tasmanian genus *Tasmanoplegas* Neboiss, 1977 was originally distinguished from *Plectrocnemia* by the stalked fork 2 in fore- and hind wings and by details in the genitalia (Neboiss,1977). However, it was synonomised with *Plectrocnemia* on the basis that other *Plectrocnemia* species from Japan, China and New Zealand also have a stalked hind wing fork 2 (Oláh and Johanson, 2010). Later, Chamorro and Holzenthal (2011), in their study of the history and phylogeny of the Polycentropodidae indicated that "the placement of *P. spilota* was unresolved in our analysis" and Johanson *et al*. (2012) following their phylogenetic analyses stated "*Tasmanoplegas* is phylogenetically distinct from *Plectrocnemia* and other genera, and therefore considered valid". The larva of *P. spilota* is unknown and its discovery may help elucidate placement of this genus and species.

Methods and Material

The abdomens of males were cleared with a KOH solution to reveal internal structures before drawing. Typically, setae or spines are illustrated only on the right side of the figure (as viewed) to enable clearer depiction of the underlying structures. Length/width (L/W) measurements generally mean maximum length

divided by maximum width. Photographs were taken using Samsung Galaxy A50 phone camera focused through microscope eyepiece, hence are not of the best quality. Figured specimens are identified by the notebook numbers of the author (prefix CT-). Leg samples sent to BOLD (http://www.boldsystems.org) for COI sequencing have been allocated DC- numbers and BOLD BIN number. Information on the methods used for sequencing and gene segment sequenced are available on the BOLD website. Depositories for specimens are abbreviated as follows: Museum of Victoria, Melbourne, Australia (MV) and Queensland Museum, Brisbane, Queensland (QM). Terminology generally follows that of Chamorro and Holzenthal (2011) and Zhong *et al.* (2012). Abbreviations for wing and genitalia characters are shown on the appropriate figures.

Systematics

Plectrocnemia Stephens, 1836: 168.

Type species *Plectrocnemia senex* Stephens

The genus *Plectrocnemia* is separated from other Polycentropodidae genera primarily on the basis of wing venation (Neboiss, 1992; Oláh and Johanson 2010, table 1; Fig. 1). *Plectrocnemia* is characterised by absence of ocelli; tibial spur formula 3:4:4; forewing with R1 not forked, forks, 1, 2 (sessile and with nygma), 3, 4 and 5 present, discoidal cell closed; hind wing with forks 1, 2 (sessile and with nygma) and 5, discoidal cell closed (except *P. spilota* which has fork 2 in both fore- and hind wings with a short footstalk (Neboiss, 1992).

General characters of known Australian species

Australian species can be generally divided into two basic groups based on the shape of the inferior appendages: one group containing *Plectrocnemia altera*, *P. australica* and *P. lacuna* all have very elongate, slender inferior appendages, whereas members of a second group, comprising *P. caudata*, *P. manicata* and *P. spilota*, have short, robust appendages. The seventh species, *P. eximia* has somewhat intermediate inferior appendages, elongate but robust at least basally.

Undescribed species of *Plectrocnemia* are known from eastern mainland Australia (Walker *et al.* 1995; author, pers. obs.). Work on the remaining new species is delayed presently due to lack of access to the Museum Victoria collections due to Coronavirus restrictions.

Plectrocnemia robotica sp. n.

Figs 1, 2, 2a, 3, 3a, 4, 4a

Holotype male (BOLD BIN no. ADF0343/DC338, drawn specimen CT-670). Queensland. E flowing creek, 14 km from NP sign, Mt Lewis Rd, 16.5944ºS, 145.2792ºE, 28 Oct 2017, D. Cartwright and R. StClair (MV).

Paratype male (DC262). Queensland. Huntsbrook Ck on Gordonvale–Atherton Hwy, 17.18ºS, 145.69ºE, 20 May 2010, J. Webb and M. Shackleton (QM).

Diagnosis. This new species is very distinctive especially in the shape of the elongate, inflexed, bifid inferior appendages and in that regard appears to be

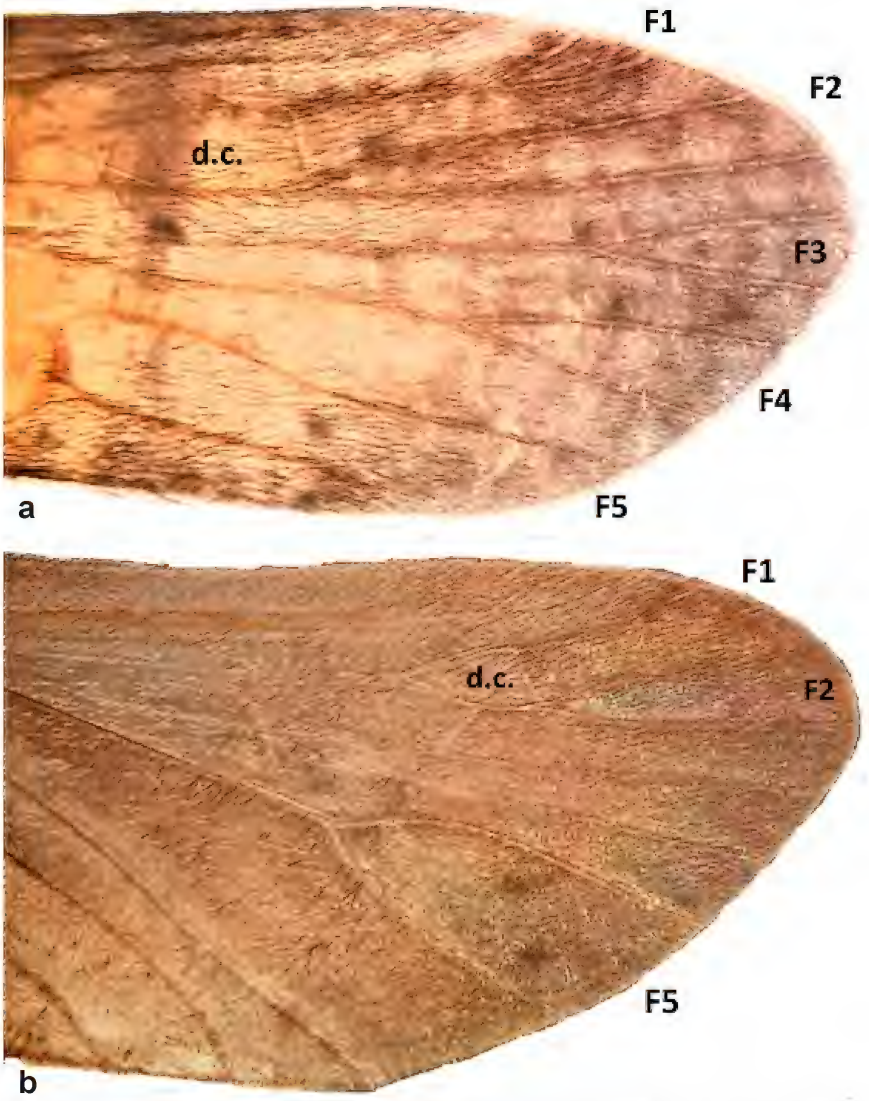


Fig. 1. *Plectrocnemia robotica* **sp. n.** Male (CT-670). (a). Part forewing. (b). Part hindwing. Abbreviations: d.c. - discoidal cell; F1 - fork 1, F2 - fork 2, F3 - fork 3, F4 - fork 4, F5 - fork 5.

dissimilar to any other Australian *Plectrocnemia* species. Several species from Vietnam and Thailand in Southeast Asia, which also have strongly inflexed inferior appendages but with simple apices. These include *P. arphachad* Malicky and Chantaramongkol, 1993 and *P. hager* Malicky, 2009, (both figured in Malicky 2010).

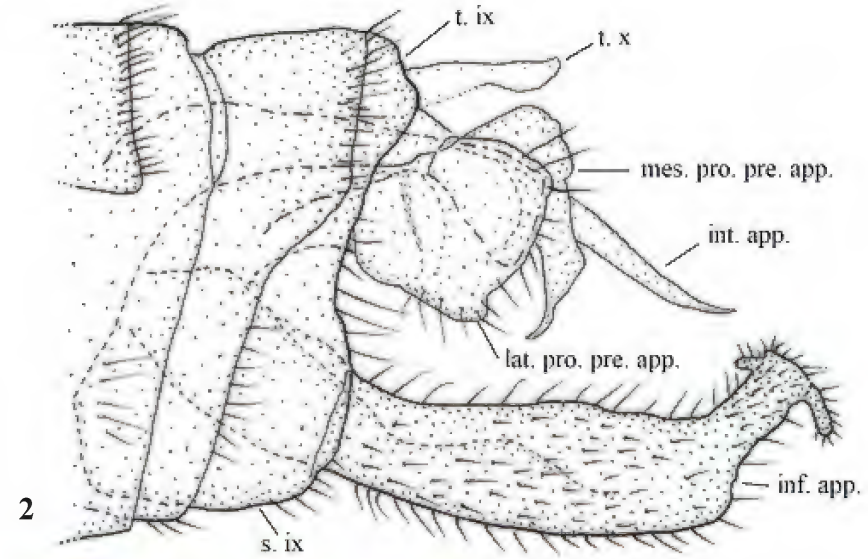
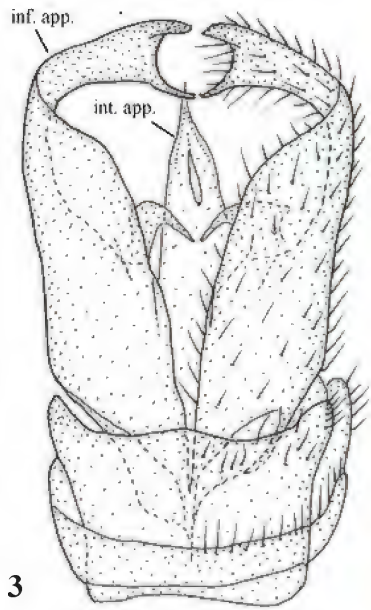
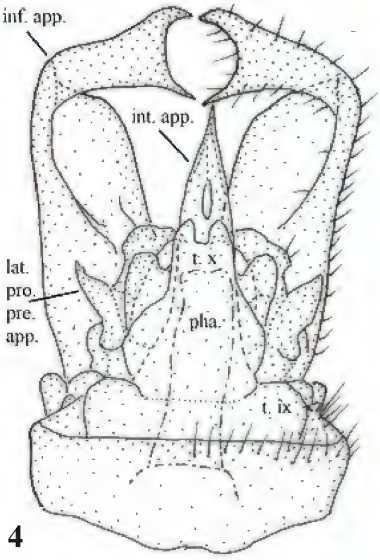


Fig. 2. *Plectrocnemia robotica* **sp. n.** Male (CT-670). Genitalia, lateral view. Abbreviations: inf. app.- inferior appendages, int. app. – intermediate appendage; lat. pro. pre. app. – lateral process of preanal appendage; mes. pro. pre. app. – mesal process of preanal appendage; pha. – phallus; s. ix – sternum IX; t. ix. – tergum IX; t. x. – tergum X.





Figs 3, 4. *Plectrocnemia robotica* **sp. n.** Male (CT-670). Genitalia. Figs 3, 3a. Ventral; Figs 4, 4a. Dorsal. Abbreviations: inf. app.- inferior appendages, int. app. – intermediate appendage; lat. pro. pre. app. – lateral process of preanal appendage; mes. pro. pre. app. – mesal process of preanal appendage; pha. – phallus; s. ix – sternum IX; t. ix. – tergum IX; t. x. – tergum X.

Description. Male. Head, nota and wings light brown. Length of forewing 7.6–8.4 mm. Wings (Fig. 1), forewing with forks 1, 2, 3, 4 and 5; fork 1 short about same length as fork, fork 2 sessile with nygma; fork 3 with fork slightly longer than footstalk; fork 4 with short footstalk; fork 5 thickened near base, discoidal cell closed, length about 4x width; hind wing with forks 1, 2 and 5; fork 1 short about same length as fork; fork 2 sessile with nygma; fork 5 broad; discoidal closed, short, length about twice width.

Male. Genitalia. Segment IX anterior margin in lateral view, slightly rounded ventrally (Fig. 2). Tergum X membranous, dorsoventrally compressed (Figs 2, 4), in dorsal view weakly bilobed (Fig. 4). Tergum IX in dorsal view with pair of rounded lobes posteriorly (Fig. 4); sternum IX with anteromesal margin straight (Fig. 3). Intermediate appendages, long, dorsoventrally compressed, fused, directed postero-ventrally (Figs 2, 2a–4, 4a), in lateral view appear slender, tapered to acute apices posteriorly (Fig. 2). Preanal appendages with partly fused lateral and mesal processes, lateral process compressed laterally, plate-like, mesal process in distal half somewhat hook-like, slender and directed mesoventrally, tapered to acute apices (Figs 2, 2a–4, 4a). Phallus hard to discern in this specimen, tube-like, without any obvious paramere spines or internal phallic sclerites (Figs 2, 4). Inferior appendages elongate, slightly compressed dorso-ventrally in basal three quarters, narrowed and strongly directed mesodorsally in posterior quarter, apices widely bifid acute (Figs 2, 2a–4, 4a); in lateral view appear subrectangular in basal three quarters (Figs 2, 2a), in ventral and dorsal views, somewhat flanged in basal three quarters (Figs 3, 3a, 4, 4a).

Female. Unknown.

Larva. Unknown.

Etymology. robotica – word for 'robot-like arms' referring to the inferior appendages with widely bifid apices.

Remarks. This is a distinctive species known from only two male specimens from two sites separated by about 160 km in north-eastern Queensland (latitudinal range 16.6–17.2 °S). The presence of the unique inferior appendages raises questions as to their special function particularly in relation to their role in grasping the female during copulation.

Acknowledgements

Many thanks to Ros StClair for helping to collect the holotype specimen and to Michael Shackleton for the loan of the paratype, also to my family for helping fund the 2017 collecting trip to North Eastern Queensland and finally to Alice Wells and Ros StClair for helpful comments on a draft of this manuscript. The holotype specimen was collected under Queensland NP permit no. WITK15549915 (The Entomological Society of Queensland).

References

BANKS, N. 1939. New genera and species of neuropteroid insects. *Bulletin of the Museum of Comparative Zoology at Harvard* **85:** 437–504. (Trichoptera pp. 479–504).

CHAMORRO, M.L. and HOLZENTHAL, R.W. 2011. Phylogeny of Polycentropodidae Ulmer, 1903 (Trichoptera: Annulipalpia: Psychomyioidea) inferred from larval, pupal and adult characters. *Invertebrate Systematics* **25:** 219–253.

JOHANSON, K.A., MALM, T., ESPELAND, M. and WEINGARTNER, E. 2012. Phylogeny of the Polycentropodidae (Insecta: Trichoptera) based on protein-coding genes reveal non-monophyletic genera. *Molecular Phylogenetics and Evolution* **65:** 126–135. http://dx.doi.org/10.1016/j.ympev.2012.05.029

MALICKY, H. 2009. Beiträge zur Kenntnis asiatischer Trichopteren. *Braueria* **36:** 11–58.

MALICKY, H. 2010. *Atlas of Southeast Asian Trichoptera*. (Edited by P. Chantaramongkol). Biology Department, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand; 346 pp.

MALICKY, H. and CHANTARAMONGKOL, P. 1993. Neue Trichopteren aus Thailand. Teil 1: Rhyacophilidae, Hydrobiosidae, Philopotamidae, Polycentropodidae, Ecnomidae, Psychomyiidae, Actopsychidae, Hydropsychidae (Arbeiten über thailändische Köcherfliegen Nr. 12). *Linzer biologische Beiträge* **25:** 433–487.

MORSE, J.C. 2020. *Trichoptera World Checklist*. https://entweb.sites.clemson.edu/database/trichopt/ (accessed 5 July 2020).

NEBOISS, A. 1977. A taxonomic and zoogeographic study of Tasmanian caddis-flies (Insects: Trichoptera). *Memoirs of the National Museum of Victoria* **38:** 1–208.

NEBOISS, A. 1982. The caddis-flies (Trichoptera) of south-western Australia. *Australian Journal of Zoology* **30:** 271–325.

NEBOISS, A. 1992. *Illustrated keys of the families and genera of Australian Trichoptera. 1. Adults.* Australian Society for Limnology Special Publication **9:** iii + 86.

OLÁH, J. and JOHANSON, K.A. 2010. Generic review of Polycentropodidae with description of 32 new species and 19 new species records from the Oriental, Australian and Afrotropical Biogeographical Regions. *Zootaxa* **2435:** 1–63.

STEPHENS, J.F. 1836–1837. *Illustrations of British entomology; or, a synopsis of indigenous insects: containing their generic and specific distinctions; with an account of their metamorphoses, times of appearance, localities, food, and economy, as far as practicable. Vol. VI. Mandibulata*. Baldwin and Cradock, London; 240 pp.

SUTER, P., DEAN, J. CARTWRIGHT, D., SUTCLIFFE, K., DAVIES, P., PINDER, A. and BRYCE, C. 2006. *Habitat profiles of selected Australian aquatic insects*. Australian government of the Environment, Water, Heritage and the Arts, Canberra. (Accessed 12 Aug. 2020) at www.environment.gov.au/biodiversity/abrs/publications/electronic-books/aquatic-insects.html

WALKER, K., NEBOISS, A., DEAN, J., and CARTWRIGHT, D. 1995. A preliminary investigation of the caddis-flies (Insecta: Trichoptera) of the Queensland wet tropics. *Australian Entomologist* **22:** 19–31.

ZHONG, H., YANG, L.F., and MORSE, J.C. 2012. The genus *Plectrocnemia* Stephens in China (Trichoptera, Polycentropodidae). *Zootaxa* **3489:** 1–24.

THREE NEW AUSTRALIAN MICROCADDISFLY SPECIES (TRICHOPTERA: HYDROPTILIDAE)

ALICE WELLS

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Abstract

Three new microcaddisfly species from south-eastern Australia are described in three genera: *Hellyethira genoa* **sp. n.**, *Acritoptila sinuosa* **sp. n.** and *Oxyethira (Trichoglene) truncata* **sp. n.** The resemblance of the new species in *Hellyethira* to the hypothesised ancestor of the *Oxyethira* subgenus *Trichoglene* is discussed.

Keywords: species delimitation, tannin-enriched waters, south-eastern Australia, biogeography

Introduction

Among Australian Trichoptera the microcaddisfly family Hydroptilidae is relatively well known. Some 158 species are recorded at present for Australia, in species richness being second only to Leptoceridae. Not unexpectedly, further new species are still accumulating in collections, and here from eastern Australia, a new species is described in the genus *Hellyethira* Neboiss, 1977 bringing to 30 species the number in that genus. In addition, one new species is described in *Acritoptila* Wells, 1982 and another in *Oxyethira* Eaton, 1873.

The males of the new *Hellyethira* species, *H. genoa* **sp. n.**, exhibit the simplest (relatively unmodified) male genitalic structures of all species in the genus. Although exhibiting features diagnostic of *Hellyethira*, the overall impression when the distal abdomen is viewed ventrally or dorsally is of a set of symmetrical genitalic structures essentially resembling those hypothesised by Kelly (1984) as 'ancestral' in *Oxyethira* Eaton and exhibited by members of the subgenus, *Trichoglene* Neboiss, 1977.

The features of *O.* (*Trichoglene*) as expanded from Neboiss' original account by Kelley (1984) are: 'Male. Antennae 27–41-segmented. Segment VIII entire, with dorsum only slightly excised. Segment IX largely retracted within segment VIII; dorsum a wide band; venter pointed anteriorly, reaching to anterior margin of segment VIII; acute posterolateral processes present; setal lobes short, located mesally to inferior appendages. Inferior appendages short, variable in shape. Subgenital processes fused to posterolateral processes of segment IX; elongate bilobed process. Aedeagus with distal recurved processes; titillator highly reduced or absent. Female. Antennae 23–33-segmented. Tergum VIII distinct; apodemes variable in length; sternum VIII with paired sclerites in some species. Tergum IX usually distinct. Spermathecal sclerite positioned at anterior end of segment VIII in most species.' To this I would add antennal flagellomeres bearing a basal ring of fimbriate setae and abundant scattered sensilla auricillica.

In contrast to species in *O.* (*Trichoglene*), in *Hellyethira* species, the antennal flagellomeres of males bear abundant *sensilla placodea* rather than *sensilla*

auricillica and the inferior appendages (claspers) are not strongly reduced in size. Major differences occur in the immature stages: the cases of *Hellyethira* are basically variants on a rectangular envelope, not the invariant flask-shape of *Oxyethira*; and the larvae of *Hellyethira* have far longer mid- and hind-legs than *Oxyethira* species.

A number of *Hellyethira* species have been described from South-East Asia and New Guinea and a single one was described from Ethiopia (Malicky & Graf 2015), well outside what appears to be the normal range of the genus. A common south-eastern Australian species is found in New Caledonia; Wells (1995) suggested that it may have been introduced there. Among the species presently known across the range of *Hellyethira* in Australia, most are endemics.

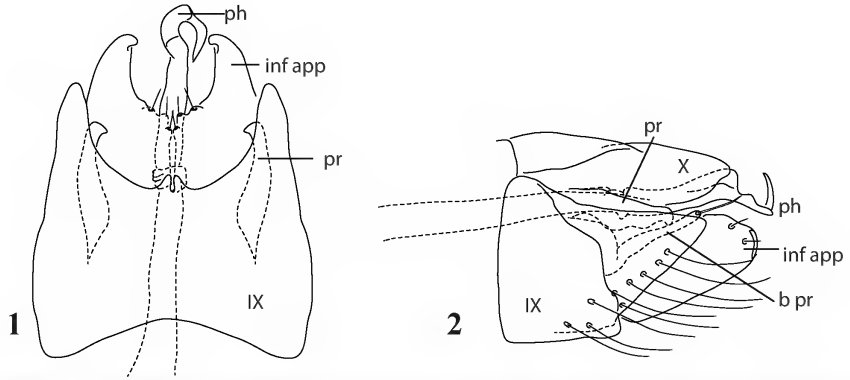
Species of *Acritoptila* are recorded from eastern and south-western Australia (Wells 1982, 1990) and New Caledonia (Kelley 1984, Wells 1995, Olah & Johanson 2010, Wells & Johanson 2014) and the *Oxyethira* subgenus *Trichoglene* from Australia, Norfolk Island New Zealand and New Caledonia (Olah & Johanson 2010, Wells & Kjer 2016, Wells & Johanson 2019).

Bushfires in the summer of 2020 severely impacted the areas in which the collecting sites of two of the species are located, namely the south-east of New South Wales and the East Gippsland area. The impact of the fires on the aquatic fauna of the water bodies is unknown.

Material and Methods

The specimens examined are from collections spread over a number of years, some taken at lights and others collected by sweeping alongside water courses with a net. Specimens were stored in 80% ethanol, and, for microscope study macerated in 10% KOH and slide-mounted in Canada balsam. Illustrations were made from slides, draft drawings traced in Adobe Illustrator, and the resultant figures arranged into plates in Adobe Photoshop. Terms used follow previous works by the author, e.g. Wells (1979), Wells & Johanson (2014). It is to be noted that the term 'paramere' as used by the author here and throughout her studies on Hydroptilidae follows Marshall (1979) who considered both 'paramere' and 'subgenital plate' to be 'non-committal' terms, the former being one of the terms applied to subgenital appendages if paired, the latter if they are fused. *Oxyethira*-group species (Wells 1987) often have both paired appendages or 'parameres' and a 'subgenital plate'. In contrast, Kelley (1980) considered them to be '… the dorsal lobes of the inferior appendages …' that have '… become detached from the ventral portions …'; and Olah & Johanson (2010) termed them 'paraprocts'.

All specimens including types are in the collection of the Australian National Insect Collection, CSIRO, Canberra (ANIC).



Figs 1, 2. *Hellyethira genoa* **sp. n.** holotype male genitalia: (1) ventral and (2) left lateral views.

Abbreviations: b pr — bilobed process; inf app — inferior appendages; ph — phallus; pr — paramere; subg —subgenital plate; VIII, IX, X, abdominal segments VIII, IX and X.

Hellyethira genoa sp. n.
Figs 1, 2

Material examined. Holotype ♂, VICTORIA: Genoa Creek, 3.5 km W of Genoa (37°29.8'S 149°39'E), UV lt, 30.xii.2004, A. Wells (ANIC, slide).

Paratypes: 27♂ (3 on slides), data as for holotype.

Diagnosis. The males of this species most closely resemble those of *H. basilobata* Wells, 1979 in having simple, basically symmetrical, paired genitalic structures, including 'clasper-shaped' inferior appendages and sclerotised parameres, although in *H. genoa* the inferior appendages are broader than those of *H. basilobata*, and lack the small mesobasal setate lobe seen in that species.

Description. Male. Fore wing length 1.8–2.0 mm (n =10). Antennae with 29–32 flagellomeres, all bearing abundant sensilla placodea. Abdominal sternite VII bearing slender, elongate medial process; segment VIII produced distally into well-developed lateral lobes. Genitalia: symmetrical in dorsal and ventral views; abdominal segment IX lateral lobes produced, triangular in lateral view; tergite X rectangular, membranous with surface covered with short sharp spicules; subgenital plate not apparent; inferior appendages stoutly clasper shaped, mesal margins concave, membranous bilobed processes slender, elongate, each bearing an apical seta; parameres stout, sclerotised, apices angled mesad; aedeagus without a titillator, with collar-like constriction at about half length, and 2 sclerotised spurs apically.

*Etymology***.** Named for the river beside which the specimens were collected.

Distribution. Known only from the type locality in East Gippsland, far north-eastern Victoria.

Remarks. Water in the small river beside which the collection was taken is always darkly stained, presumably enriched by tannins leached from leaves and bark. A collection of 12 females taken with the male specimens described above are unlikely to be females of this new species as they resemble so very closely females of a species of *Acritoptila* from New Caledonia.

Acritoptila sinuosa sp. n.
Figs 3–7

Material examined. Holotype ♂, VICTORIA, Genoa Creek, 3.5 km W of Genoa (37°29.8'S 149°39'E), 30.xii.2004, A. Wells (ANIC, on slide).

Paratypes: VICTORIA: 1♂, 12♀♀ (2 on slides), data as for holotype; 1♂ (head missing), Genoa Creek, 4 km W of Genoa, 8.xii.2003, UV lt, D. Cartwright. NEW SOUTH WALES: 1♂, 'creek on Batemans Bay road' [Mongarlowe River], E of Braidwood, 14.xii.1987, sweep net, A. Wells.

Diagnosis. In the form of the male genitalia with strongly reduced inferior appendages and prominent parameres, this new species shows some resemblance to the Western Australian *A. globosa* Wells, 1982 in the form of the parameres, and to *A. margaretae* Wells, 1982, from SW Western Australia in having well-developed lateral lobes on abdominal segment IX; the female is similar to that of the New Caledonian species, *Acritoptila crinita* Kelley, 1989. It is distinguished from both by the very prominent pair of elongate subapical setae on the dorsal plate, a feature not seen in any other congeneric species.

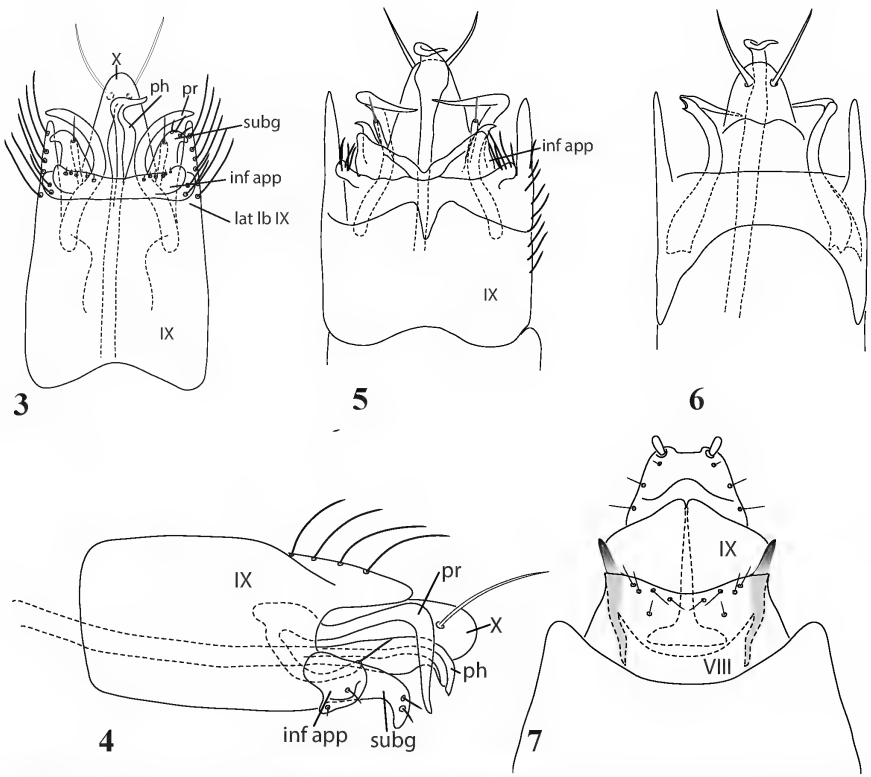
Description. Male. Length of forewing, 2.9–3.1 mm (n =3). Antennae with 38 flagellomeres. Abdominal segment VII bearing slender elongate process medially. Genitalia: abdominal segment IX produced distally into lateral lobes, slender in ventral view, subtriangular in lateral view; dorsal plate elongate, apically rounded, paired elongate setae subapically; inferior appendages short, triangular in ventral view, in lateral view rounded; subgenital plate forming paired stout processes, downturned toward apices, paired membranous setate lobes dorsal to subgenital plate, laterally paired sclerotised parameres strongly curved or sharply angled ventrad, apices acute.

Female. Length of forewing 1.9–2.5 mm (n = 10). Antennae with 22–24 flagellomeres. Abdominal terminalia of females with sharp, darkly sclerotised apices on the lateral lobes of abdominal segment IX and sternite IX distally membranous, apically triangular and cleft.

Etymology. Named for the strongly curved or sinuous parameres of the male.

Distribution. Known from the type locality in in East Gippsland, far north-eastern Victoria and from further northwards in south-eastern New South Wales.

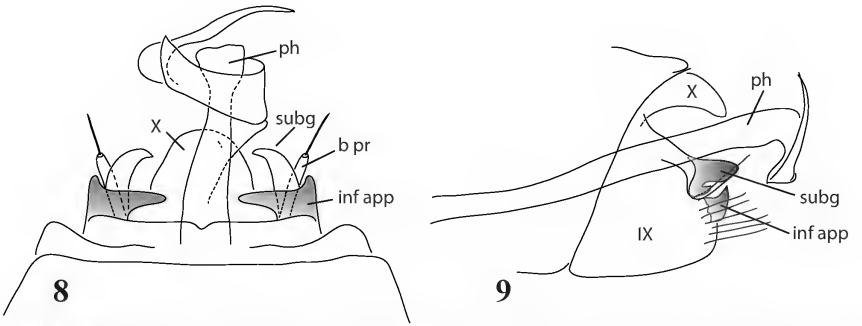
Remarks. A single species is recognised tentatively despite the variation in form of the male parameres and difference in appearance of the fused inferior appendages. The three males from the type locality are all closely similar, the parameres being sharply angled ventrad compared with the sinuous parameres of the single male



Figs 3–7. *Acritoptila sinuosa* **sp. n.:** (3, 4) holotype male genitalia, ventral and left lateral views; (5, 6) male genitalia Mongarlowe River form, (5) ventral and (6) dorsal views; (7) female terminalia, ventral view.

Abbreviations: b pr — bilobed process; inf app — inferior appendages; lat lb IX —lateral lobe of segment IX; ph — phallus; pr — paramere; subg —subgenital plate; VIII, IX, X, abdominal segments VIII, IX and X.

from further north. However, since the form of the dorsal plate with the two very long setae is unique in the genus, and both samples are from very similar slow-flowing tannin enriched streams, until further material is available a conservative approach is taken, assigning them to a single species. Twelve females taken with the Genoa Creek specimens of this species and the more abundant *Hellyethira genoa* are associated with this species as they show extraordinary resemblance to females of the New Caledonian species, *A. crinita* (see Wells & Johanson 2014). Perhaps such close similarity in the females of the two species is unsurprising, since close ties and multiple dispersal events have been demonstrated between Australia and New Caledonia for a number of groups of organisms (e.g. see Espeland 2010, Natier et al. 2017, Toussaint et al. 2017).



Figs 8, 9. *Oxyethira* (*Trichoglene*) *truncata* **sp. n.**: holotype male genitalia, (8) ventral and (9) left lateral views.

Abbreviations: b pr — bilobed process; inf app — inferior appendages; ph — phallus; pr — paramere; subg —subgenital plate; IX, X, abdominal segments IX and X.

Oxyethira (*Trichoglene*) *truncata* sp. n.
Figs 8, 9

Material examined. Holotype ♂, NEW SOUTH WALES, 'creek on Batemans Bay road' [Mongarlowe River], E of Braidwood, 14.xii.1987, A. Wells, sweep net (ANIC).

Paratype. 1♂, VICTORIA: Tolmie, 29.i.1983, A. Neboiss (ANIC).

Diagnosis. *Oxyethira truncata* **sp. n.** clearly belongs in the subgenus *Trichoglene*, showing resemblance to *O. columba* but differing in the overall distally truncate form of the male abdomen, the rather pick-shaped appearance of the inferior appendages in ventral view and the flag-like form of the apical process on the aedeagus.

Description. *Male*. Length of 2.0 mm. Antennae 28-segmented. Genitalia, short and truncate in overall appearance, both specimens with segment IX well retracted into VIII: dorsal plate membranous, broadly rounded apically; inferior appendages short, broadly pick-shaped in ventral view, parameres short and stout, setal lobes elongate, dorsally paired membranous setal lobes; aedeagus apically with broad-based, tapering flaglike process.

Etymology. The name is descriptive of the overall appearance of the terminal abdomen of the male.

Distribution. Recorded from the type locality in south-eastern New South Wales and from one site in the north-eastern Victoria, in the high country north-east of Mansfield.

REFERENCES

EATON, A. 1873. On the Hydroptilidae, a family of the Trichoptera. *Transactions of the Royal Society of London* **1873:** 125–151, pls. 2 and 3. https://doi.org/10.1111/j.1365-2311.1873.tb00639.x

ESPELAND, M. and JOHANSON, K.A. 2010. The diversity and radiation of the largest monophyletic animal group on New Caledonia (Trichoptera: Ecnomidae: *Agmina*). *Journal of Evolutionary Biology* **23:** 2112–2122. https://dx.doi.org/10.1111/j.1420-9101.2010.02072.x

KELLEY, R.W. 1984. Phylogeny, morphology and classification of the micro-caddisfly genus *Oxyethira* Eaton (Trichoptera: Hydroptilidae). *Transactions of the American Entomological Society* **110:** 435–446.

KELLEY, R.W. 1989. New species of micro-caddisflies (Trichoptera: Hydroptilidae) from New Caledonia, Vanuatu and Fiji. *Proceedings of the Entomological Society of Washington* **91:** 190–202.

MALICKY, H. and GRAF, W. (2015) Einige neue afrikanische Köcherfliegen (Trichoptera). *Braueria* **42:** 31–35.

NATTIER, R., PELLENS, R., ROBILLARD, T., JOURDAN, H., LEGENDRE, F., CAESAR, M., NEL, A. and GRANDCOLAS, P. 2017. Updating the phylogenetic dating of New Caledonian biodiversity with a meta-analysis of the available evidence. *Nature Scientific Reports* **7:** Art. 3705. https://dx.doi.org/10.1038/s41598-017-02964-x

NEBOISS, A. 1977. A taxonomic and zoogeographic study of Tasmanian caddis-flies (Insecta: Trichoptera). *Memoirs of the national Museum of Victoria* **38:** 1–208, pls. 1–3.

OLÁH, J. and JOHANSON, K.A. 2010. Description of 46 new Old World Hydroptilidae (Trichoptera). *Folia Entomologica Hungarica* **71:** 65–155.

TOUSSAINT, E.F.A., TÄNZLER, R., BALKE, M. and RIEDEL, A. 2017. Transoceanic origin of microendemic and flightless New Caledonian weevils. *Royal Society Open Science* **4:** 160546. https://dx.doi.org/10.1098/rsos.160546

WELLS, A. 1979. A review of the Australian genera *Xuthotrichia* Mosely and *Hellyethira* Neboiss (Trichoptera : Hydroptilidae), with descriptions of new species. *Australian Journal of Zoology* **27:** 311–329. https://doi.org/10.1071/ZO9790311

WELLS, A. 1982. *Tricholeiochiton* Kloet & Hincks and New Genera in the Australian Hydroptilidae (Trichoptera). *Australian Journal of Zoology* **30:** 251–270. https://doi.org/10.1071/ZO9820251

WELLS, A. 1987. On the biogeography of the *Oxyethira* group, tribe Hydroptilini (Hydroptilinae, Hydroptilidae, Trichoptera. Pp. 133–138 *in* M. Bournaud et al. (eds.) *Proceedings of the Fifth International Symposium on Trichoptera*. Dr W. Junk Publishers, Dordrecht.

WELLS, A. 1995. New Caledonian Hydroptilidae (Trichoptera), with new records, descriptions of larvae and a new species. *Aquatic Insects* **17:** 223–239. https://doi.org/10.1080/01650429509361591

WELLS, A. and KJER, K. 2016. Norfolk Island's caddisfly is a New Zealander (Trichoptera: Hydroptilidae). *Australian Entomologist* **43:** 49–54.

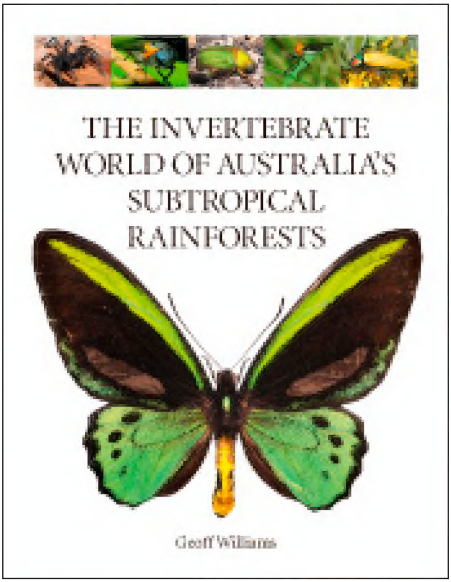
WELLS, A. and JOHANSON, K.A. 2014. Review of the New Caledonian species of *Acritoptila* Wells, 1982 (Trichoptera, Insecta), with descriptions of 3 new species. *ZooKeys* **397:** 1–23. https://dx.doi.org/10.3897/zookeys.397.7059

WELLS, A. and JOHANSON, K.A. 2019. New Caledonia's Trichoptera—present status of knowledge. *Zoosymposia* **14:** 87–102. https://dx.doi.org/10.11646/zoosymposia.14.1.12

BOOK REVIEW

The Invertebrate World of Australia's Subtropical Rainforests. By Geoff Williams. CSIRO Publishing, Melbourne (1 Sept 2020), hardcover, 215 x 280 mm, 392 pp. ISBN: 9781486312917. AU$195.00.

The author of this book is one of New South Wales' best-known naturalists in the fields of both entomology and botany and has lived as a 'freelance' biologist for most of his adult life. He is a long term Honorary at the Australian Museum from where much of his scientific support comes and is a long-term collaborator with botanist Paul Adam at UNSW. Geoff Williams has a PhD in pollination ecology of rainforest plants from UNSW and has twice received Australian Honours (OAM 2002, AM 2018) for his work in conservation and vegetation management. He lives on a private rainforest nature reserve he developed with his family in the foothills of the Great Divide, inland from Taree, in the heart of Australia's subtropical rainforests that became his life's passion



Geoff publishes widely on insect pollination, jewel beetle taxonomy, dung beetle distribution and habitat regeneration. In 1993 he published a 190 page book entitled *Hidden Rainforests: Subtropical Rainforests and their Invertebrate Diversity.* Then, in 2002–2003, driven by the need to document the Gondwana Rainforests World Heritage Area, he prepared two extensive invertebrate summaries, totalling more than 300 pages, published by the Australian Museum and the NSW National Parks Service. The present book is really an amalgamation of those three earlier works but updated with 20 years of new literature and presented as a glamorous, full-colour, hard cover book. Its coverage is extended a little from the earlier works to cover rainforests from near Rockhampton in Queensland right down to the lowland rainforest patches on the extreme south coast of NSW.

At its most basic the book is a giant literature review, with 60 pages of literature citations at the rear, covering right up to 2018. For that very reason it should be the 'go to' first resource for anyone interested in the bewildering array of invertebrates of the rich region it covers. But by the time it has 300 colour plates of the living invertebrates themselves and an absolute wealth of unpublished personal observations by the author himself, it become a much greater work. One

error noted in the photo captions is that the scorpion fly in Plate 191 is not a *Harpobittacus* in the Bittacidae, but a member of the family Choristidae.

The book starts with describing where rainforest occurs within the target region, then tackles the fraught area of definitions of rainforest sub-forms which have always taken a divergence between more taxon/climate definitions in NSW and structure-based definitions in Queensland. Then follows a short overview of the modern literature on ecology of rainforest invertebrates including pollination, herbivory, canopy diversity, flightlessness, parasitism and so on.

The core of the book is the systematic treatment, group by group, of all the invertebrate taxa. While insects occupy the bulk of this treatment it is refreshing to see summaries of the often-obscure literature on groups such as land nemerteans, flatworms, earthworms, leeches, velvet worms and terrestrial crustacea. The insects are treated family by family, often with an initial summary of fossil history followed by details of diversity and distribution within the study zone and a wealth of interesting observations on natural history and plant associations.

Throughout the book small, but fascinating, essays on diverse topics are presented in text 'boxs'. These cover such fields as fly pollination, scarab dimorphism, chemical defences of carabids, canopy insects, Wallace and evolution, H.J. Carter's collecting trips and mite diversity. It is a pity they are not indexed separately.

This is a book we should all have, and the good news is that Geoff Williams' earlier 2010 book with Paul Adam, *The Flowering of Australia's Rainforests: a Plant and Pollination Miscellany,* is also being updated and the second edition will be published by CSIRO Publishing in due course, hopefully during 2021.

Reviewed by Geoff Monteith.

NOTES FOR AUTHORS

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